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MEASUREMENTS OF BEND FLOW HYDRAULICS ON THE FALL RIVER AT BANKFULL STAGE

WRD PROJECT REPORT NO. 85-3

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WATER RESOURCES DIVISION
NATIONAL PARK SERVICE
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523

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MEASUREMENTS OF BEND FLOW HYDRAULICS ON THE FALL RIVER AT BANKFULL STAGE

WRD Project Report No. 85-3

Submitted to:

Water Resources Division
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by

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INTRODUCTION

This report documents field measurements of bend flow hydraulics and sediment characteristics made at about bankfull discharge on the Fall River, Rocky Mountain National Park. This work continues that begun in 1983 and reported in an earlier WRFSL project report (Thorne, Rais, Zevenbergen, Bradley and Julien, WRFSL Report No. 83-9P, 1983).

The previous data were collected during comparatively low flow conditions on the recession of the 1983 snowmelt runoff hydrograph. The data presented here correspond to a much higher flow of around 4 m^3/s (140 cfs) which constitutes bankfull discharge in the study reach.

Measurements were made by a team of researchers over a four-day period of almost steady flow. The complete data set is presented in this report because it is not possible to publish the data in scientific journals owing to limitations on manuscript length. Two journal articles based on the data (1983 and 1984) have already appeared in print and those interested in data interpretation are referred to these papers:

Thorne, C. R. and Rais, S., 1984, "Secondary Current Measurements in a Meandering River" in River Meandering, ASCE Specialty Publication - Proceedings of the Conference on Rivers '83, pp. 675-686.

Thorne, C. R., Zevenbergen, L. W., Pitlick, J. C., Rais, S., Bradley, J. B. and Julien, P. Y., 1985, "Direct Measurements of Secondary Currents in a Sand-Bed River," Nature, 27 June 1985, pp. 745-747 (see Appendix 1).

It is the authors' intention that the data be available for use by other researchers. This report contains some overlap with the previous one in order that it can stand alone as a complete documentation of the 1984 work, as well as be taken as a continuation of the earlier report.

FIELD SITE

The field site is located on the Fall River at Horseshoe Park in Rocky Mountain National Park, Colorado (Fig. 1). This reach of river has been intensively studied since it was devastated by the Lawn Lake dam failure of July 15, 1982. Although the impact of the dam break flood on the actual study reach used for secondary flow measurements was minor, the reach has experienced vastly increased sediment supply from upstream areas, which were heavily impacted (Pitlick and Thorne, 1985).* In particular the pre-1982 cobble bed of the Fall River has been buried by a sand bed which is mobile at all flow stages.

In the study reach the river is highly sinuous (sinuosity 2.2) with stable banks of meander belt silts and clays, strongly bound together by willows (salix). The annual hydrograph is dominated by snowmelt runoff between May and August, supplimented by thunderstorm events, especially in July. Our 1983 estimate of bankfull discharge of 5.7 m^3/s (200 cfs) proved to be rather too high. On the basis of measurements made at bankfull in 1984, the revised figure is 4 m^3/s (140 cfs). The channel slope is around 1 percent and the bed material is coarse sand moving in ripples, dunes and, in places, as suspended load.

INSTRUMENTATION

The channel was not remapped in 1984. The pegs used to define section endpoints in 1983 were still in place, and these same points of reference were used to define planform locations. Water surface and bed

*Pitlick, J. C. and Thorne, C. R., 1985, "Sediment Supply, Movement and Storage in an Unstable Gravel-Bed River," Proceedings of the Workshop on Sediment Transport Problems in Gravel-Bed Rivers, Colorado State University, August 11-17, 1985.

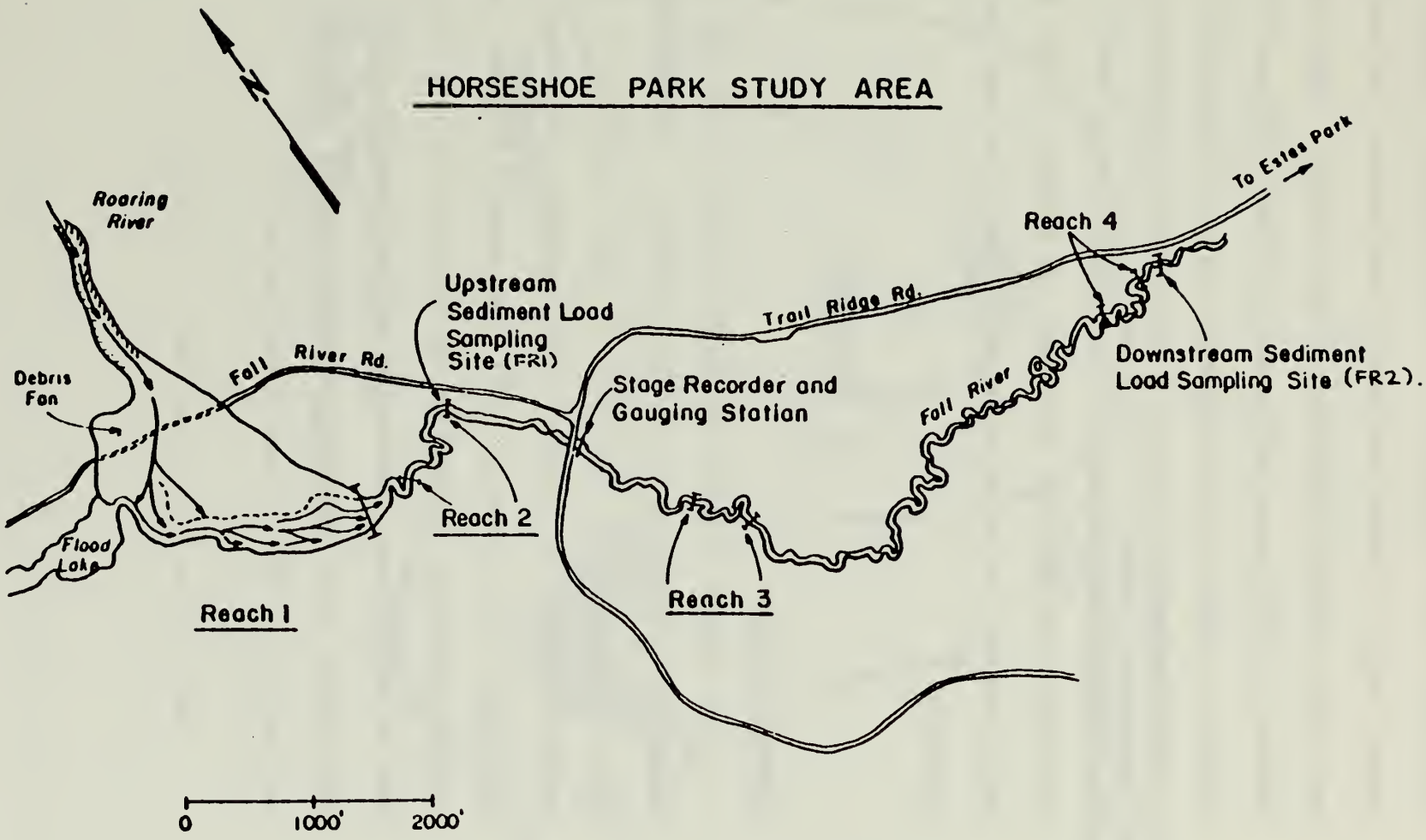


Figure 1. Field Study Site on the Fall River at Horseshoe Park in Rocky Mountain National Park

topography were established by leveling along 17 sections across the channel using a transit and staff. Bed material was sampled using a bucket-type sampler developed by Jeff Bradley. Bed forms were not sketched in 1984 because the greater flow depths obscured the bed sufficiently to make this too subjective to be scientifically meaningful.

Velocities were measured with the same Marsh-McBirney Model 511 two-component electromagnetic current meter as was used in 1983. Each measurement was made for one minute, the average x and y velocities being recorded on an HP-3421A Data Acquisition Unit and an HP-41CV calculator.

FIELD DATA

Channel Planform

The channel planform is shown in Fig. 2 and the corresponding geometrical parameters are listed in Table 1. The sections used were those established in 1983--that is, main sections 0 to 8 and intermediate sections 0A to 7A. This numbering system was adopted for consistency with previous work and because primary and secondary currents cannot be resolved for the first (0) and last (8) sections. In 1983 velocities were measured at nine sections (0 to 8). In 1984 the measurements were repeated at these sections plus the intermediate sections (0A to 7A), to make 17 sections in all.

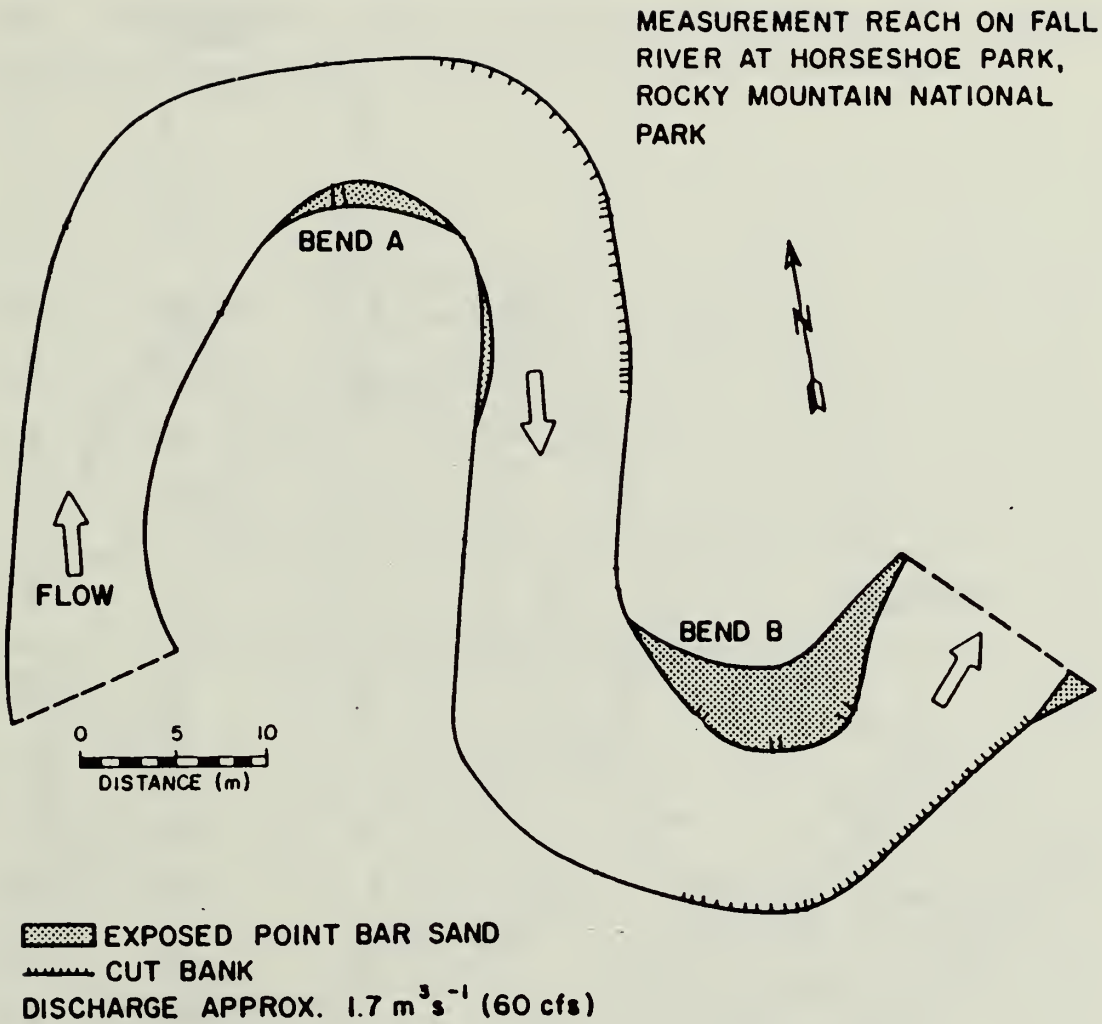


Figure 2. Measurement Reach on Fall River

Table 1. Channel Planform Parameters, July 3-6, 1984, Bankfull Discharge

Bend	Radius of Curvature (m)	Bend Arc Angle (°)	Section Number	Section Arc Angle (°)	Width (m)	Mean Depth (m)
-	-	-	0	Upstream of Bend A	9.6	0.93
			0A	0	7.2	0.82
			1	10	9.3	0.70
			1A	30	9.9	0.68
A	11.0	170	2	70	7.2	0.86
			2A	110	8.1	0.79
			3	140	8.3	0.73
			3A	170	8.1	0.72
Inflexion	-	-	4	0	8.0	0.84
			4A	35	10.3	0.72
			5	65	10.5	0.81
			5A	80	11.5	0.70
B	13.5	155	6	100	10.9	0.61
			6A	115	10.3	0.79
			7	140	7.3	0.81
			7A	150	10.2	0.69
	-	-	8	Downstream of Bend B	13.2	0.47

Water Surface Topography

Water surface topography was surveyed by leveling along the 17 sections through the study reach (Fig. 3). Readings were spaced at 0.5 meter intervals across each section. The consistency of the contours of water surface elevation suggests that errors were not too great. A confidence limit of about ±15 mm (0.05 ft) is probably realistic for these data.

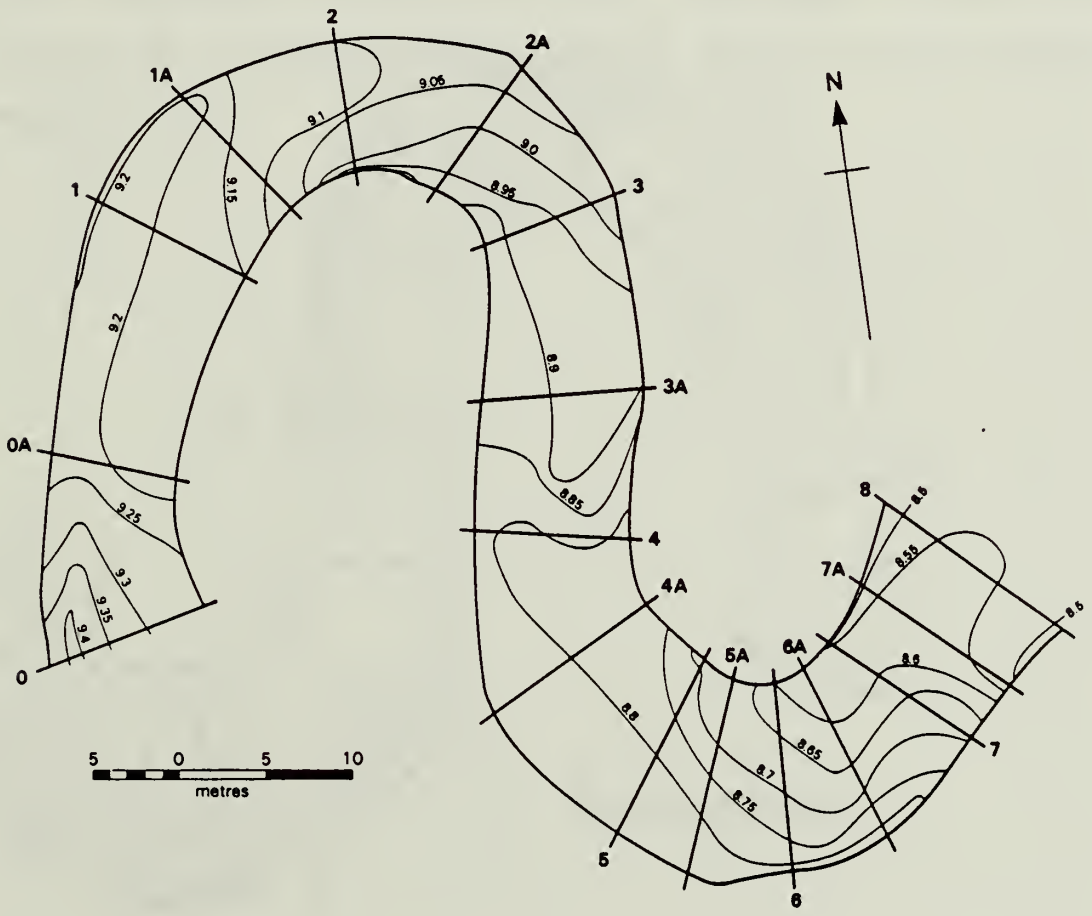


Figure 3. Water Surface Topography in Study Reach, July 3-6, 1984 (Heights are in feet above the arbitrary datum established in 1983. 1 ft = 0.3048 m)

Bed Topography

Bed topography was surveyed by leveling at the same time and locations as the water surface topography (Fig. 4). It was attempted to measure to mid-height on the bed forms but this was difficult to do consistently, especially in the deep pools. A confidence limit of about ±5 cm (0.16 ft) is probably realistic for these data.

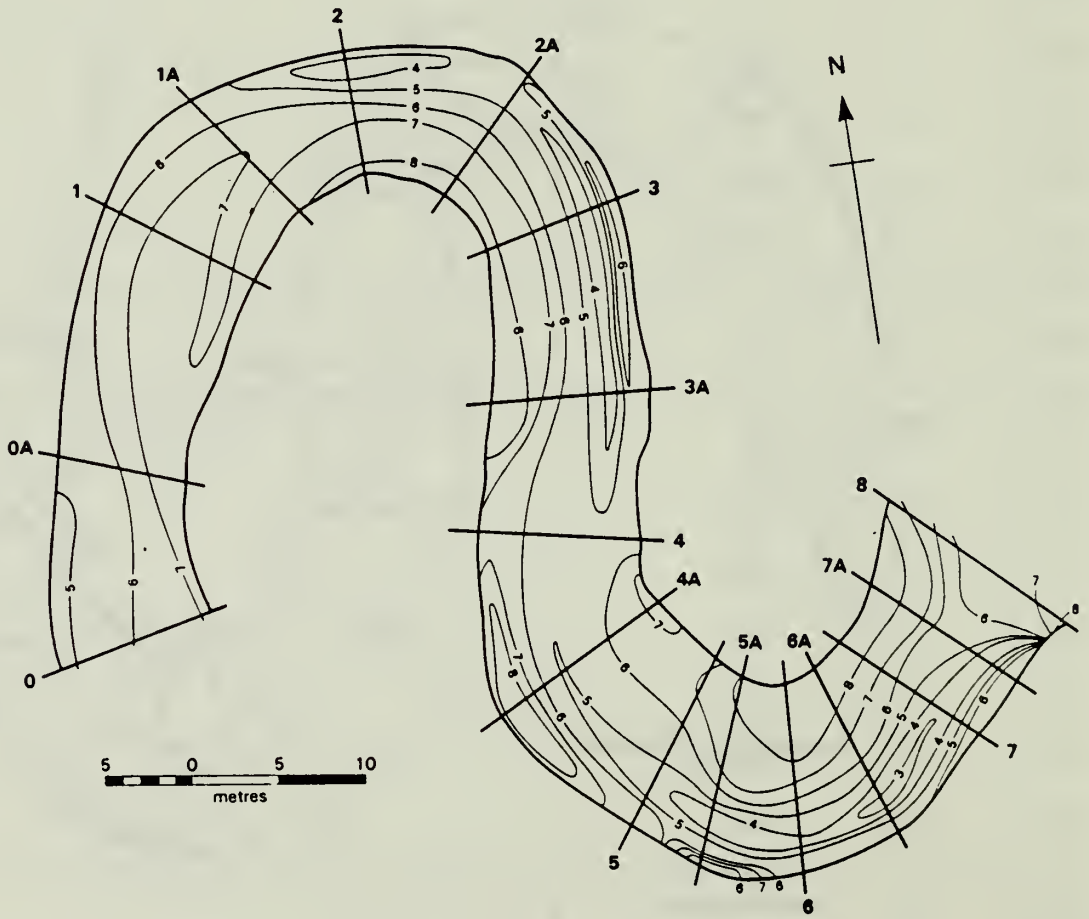


Figure 4. Bed Topography in Study Reach, July 3-6, 1984 (Heights are in feet above the arbitrary datum established in 1983. 1 ft = 0.3048 m)

Bed Material Size Distributions

Bulk samples of bed material were collected at five points across each of the nine main sections (0 to 8), and at Section 0A. The sampling points corresponded to left bank, left-center channel, center channel, right-center channel and right bank. Samples were collected using a scoop sampler developed by Jeff Bradley which was designed to sample through the bed form and to retain fine material.

Samples were oven dried and sieved using standard techniques. The size distributions are listed in Table 2 and plotted in Fig. 5. The distribution of median diameters over the bed in the study reach is shown in Fig. 6.

Table 2. Bed Material Size Distributions by Dry Sieving

Section	Size (inch)	Weight (gm) Left	Left Center	Center	Right Center	Right	Size (mm)
0	0.6250	0	0	0	0	0	16
	0.3750	0	0	0	9.6	0	9.510
	0.1870	0	0.2	0.4	68.6	0.5	4.760
	0.0937	0	4.2	3.7	177.6	27.2	2.360
	0.0469	0.6	32.5	53.6	277.3	97.3	1.190
	0.0234	12.2	247.4	251.9	244.2	90.9	0.595
	0.0117	168.4	259.5	139.9	64.1	19.2	0.297
	0.0029	96.7	15.5	5.1	3.8	2.5	0.074
	PAN	2.4	0.3	0.2	0.4	0.6	PAN
0A	0.6250	24.5	0	0	0	0	16
	0.3750	0	2.2	0	0	0	9.510
	0.1870	16.1	4.7	13.3	0	13.7	4.760
	0.0937	94.4	28.9	73.5	13.6	101.1	2.360
	0.0469	246.7	114.4	199.3	105.7	275.6	1.190
	0.0234	258.5	248.3	280.6	263.3	276.7	0.595
	0.0117	66	104.2	93.5	67.3	69.1	0.297
	0.0029	1.9	4.8	3.2	11.3	2.3	0.074
	PAN	0.1	0.2	0.1	0	0	PAN
1	0.6250	39	7.2	0	0	0	16
	0.3750	15.6	7.5	4.2	0	0	9.510
	0.1870	9.9	12.6	40.6	16	4.7	4.760
	0.0937	18.7	36.9	120.3	94	41.9	2.360
	0.0469	108.9	98.3	147.5	218.6	176.5	1.190
	0.0234	349.3	413.8	132.6	227.7	283.1	0.595
	0.0117	167.5	0	31.8	86.5	139.4	0.297
	0.0029	14.6	12	6.2	5.8	14.2	0.074
	PAN	0.2	0.3	0.4	0	0.1	PAN
2	0.6250	124.7	0	0	0	11.1	16
	0.3750	15.7	0	0	0	38.4	9.510
	0.1870	37.1	0.6	8	14	116.6	4.760
	0.0937	72.5	8.4	30	47.8	207.6	2.360
	0.0469	79.7	72.2	97.4	130.7	184.5	1.190
	0.0234	91.3	270	184.8	257.4	99.1	0.595
	0.0117	48.8	212.4	75.1	176.9	19.8	0.297
	0.0029	2.5	34.7	2.7	13.8	1.5	0.074
	PAN	0.3	0.4	0.3	0.3	0.2	PAN
3	0.6250	0	0	0	0	22.7	16
	0.3750	0	0	0	0	69.9	9.510
	0.1870	0.3	6.3	3.6	0.8	182	4.760
	0.0937	0.2	50.8	46.7	2	350.8	2.360
	0.0469	9.5	121.6	247.6	26.1	269.9	1.190
	0.0234	187.7	43	330.9	266.9	54.1	0.595
	0.0117	343.2	1.7	59.3	233.7	69.2	0.297
	0.0029	38	0.3	2.7	13.8	33.6	0.074
	PAN	0.2	0.1	0.1	0.1	0.9	PAN

Table 2. (continued)

Section	Size (inch)	Weight (gm) Left	Left Center	Center	Right Center	Right	Size (mm)
4	0.6250	18.4	8.1	0	0	0	16
	0.3750	10.4	7.2	0	0	0	9.510
	0.1870	97.7	49.7	0	0	0	4.760
	0.0937	322.9	156.2	8.3	1.1	0.3	2.360
	0.0469	239.8	267.9	101.8	19.2	2.8	1.190
	0.0234	29.9	273.3	426.6	146.8	69.7	0.595
	0.0117	11.4	69.5	179.5	116.8	256.6	0.297
	0.0029	5	4.2	7.6	9	33.4	0.074
	PAN	0.6	0.3	0.2	0.2	0	PAN
5	0.6250	0	0	0	0	0	16
	0.3750	5.8	3.5	3.8	0	0	9.510
	0.1870	67.5	18.4	4.4	0.7	0	4.760
	0.0937	232.1	94.2	6.3	2	0	2.360
	0.0469	271.9	262.1	54.2	17.9	1.5	1.190
	0.0234	103.2	273.4	205.4	117.2	7.1	0.595
	0.0117	25.5	65	119	132.5	44.4	0.297
	0.0029	3.4	4	8.6	10.3	92.5	0.074
	PAN	0.2	0.2	0.2	0.3	6.5	PAN
6	0.6250	7.6	0	0	0	NA	16
	0.3750	8.6	1.5	8.5	0	NA	9.510
	0.1870	49.3	17.3	36.2	10.9	NA	4.760
	0.0937	122.7	76.7	99.8	53.7	NA	2.360
	0.0469	153.6	136.7	207.2	144.9	NA	1.190
	0.0234	92.4	94.1	287.6	207.1	NA	0.595
	0.0117	51.8	46	99.8	44.2	NA	0.297
	0.0029	16.8	5.3	6.9	2.4	NA	0.074
	PAN	1	0.4	0.5	0	NA	PAN
7	0.6250	0	0	0	15.9	218	16
	0.3750	0	0	0	21.8	299	9.510
	0.1870	10.1	1.3	4.1	46.6	169.2	4.760
	0.0937	82	12.3	12.9	126.5	131	2.360
	0.0469	191.1	105.3	88.9	261.9	39.6	1.190
	0.0234	113.1	236.1	184.9	258.1	19.6	0.595
	0.0117	89.3	176.7	101.7	66.2	82.4	0.297
	0.0029	97	15.6	6.5	14	39.8	0.074
	PAN	3	0.3	0.1	0.3	1.4	PAN
8	0.6250	0	0	0	293.9	0	16
	0.3750	0	0	0	86.3	0	9.510
	0.1870	0	0	8.6	95.9	15.7	4.760
	0.0937	0.3	1.1	79	169.2	153.4	2.360
	0.0469	0.1	3.7	243.9	139.4	292.3	1.190
	0.0234	14.2	62.5	307.2	130.8	146.5	0.595
	0.0117	154.8	76.8	94.2	51.4	55	0.297
	0.0029	123.4	6.2	5.6	22.7	40.6	0.074
	PAN	4.2	0.1	0.3	0.7	0.7	PAN

Right center sample includes one pebble 41.4 gm which will not pass the 32 mm sieve size on the gravelometer.

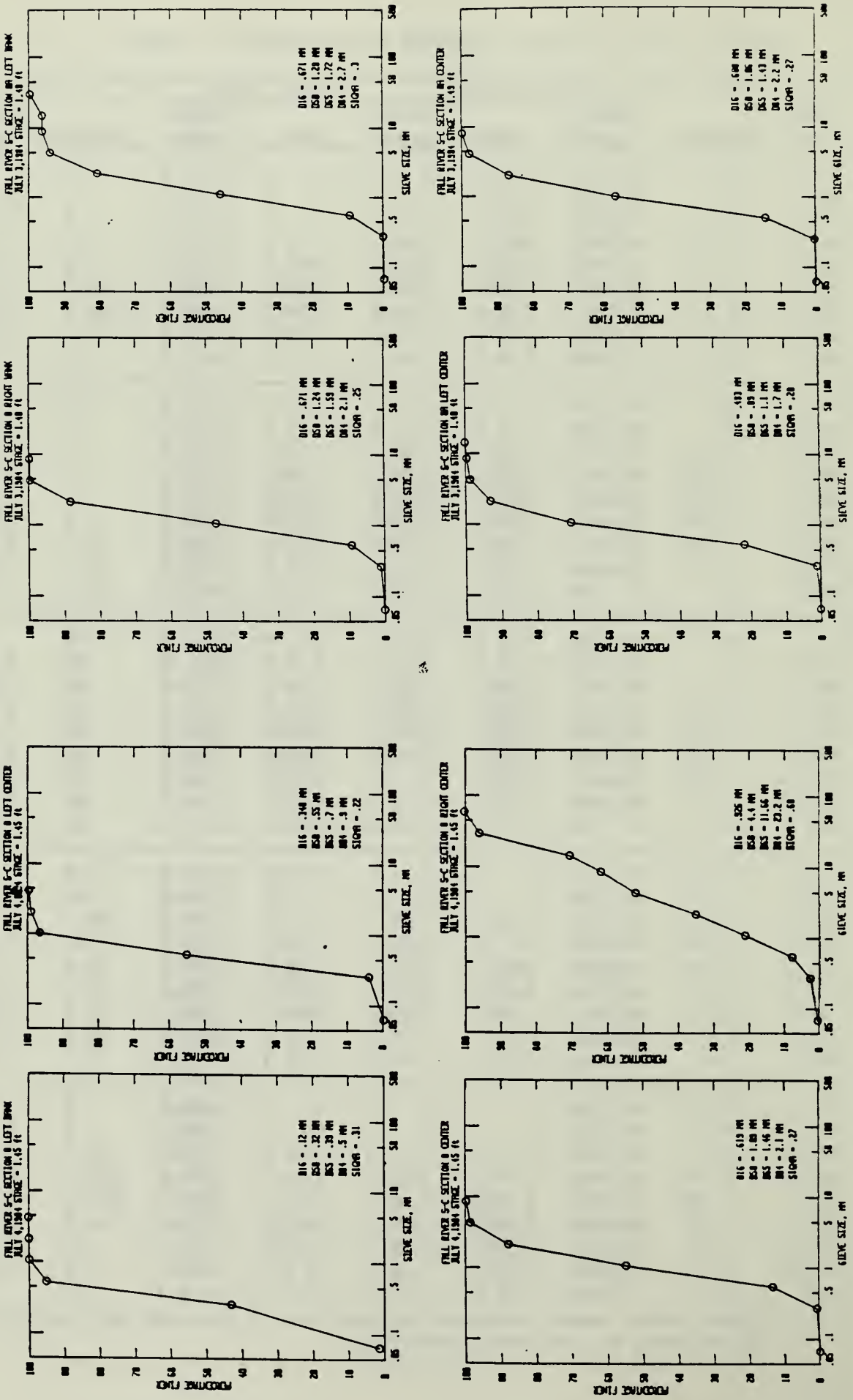


Figure 5. Size-Frequency Curves for Bed Material, July 3, 1984

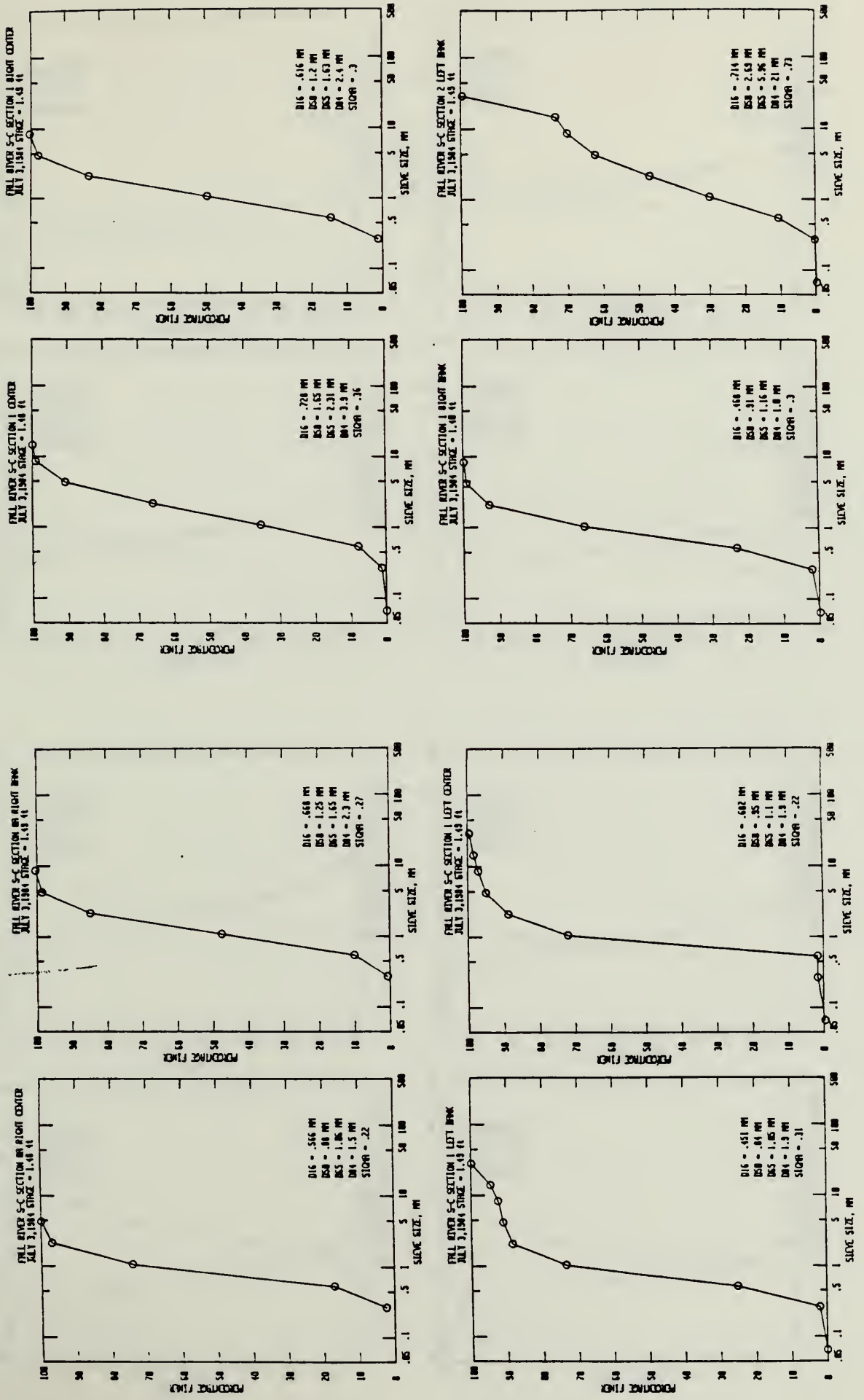

FALL RIVER S-C SECTION 1 RIGHT CENTER
JULY 3,1984 STAGE = 1.49 ft
D16 = .616 mm
D50 = 1.2 mm
D65 = 1.63 mm
D84 = 2.9 mm
SIGMA = .3
FALL RIVER S-C SECTION 2 LEFT BANK
JULY 3,1984 STAGE = 1.49 ft
D16 = .714 mm
D50 = 2.53 mm
D65 = 5.96 mm
D84 = 21 mm
SIGMA = .73
FALL RIVER S-C SECTION 1 CENTER
JULY 3,1984 STAGE = 1.49 ft
D16 = .728 mm
D50 = 1.65 mm
D65 = 2.31 mm
D84 = 3.9 mm
SIGMA = .36
FALL RIVER S-C SECTION 1 RIGHT BANK
JULY 3,1984 STAGE = 1.49 ft
D16 = .468 mm
D50 = .91 mm
D65 = 1.16 mm
D84 = 1.8 mm
SIGMA = .3
FALL RIVER S-C SECTION 1 LEFT CENTER
JULY 3,1984 STAGE = 1.49 ft
D16 = .668 mm
D50 = 1.25 mm
D65 = 1.65 mm
D84 = 2.3 mm
SIGMA = .27
FALL RIVER S-C SECTION 1 LEFT CENTER
JULY 3,1984 STAGE = 1.49 ft
D16 = .682 mm
D50 = .95 mm
D65 = 1.1 mm
D84 = 1.3 mm
SIGMA = .22
FALL RIVER S-C SECTION 1 RIGHT CENTER
JULY 3,1984 STAGE = 1.49 ft
D16 = .566 mm
D50 = .88 mm
D65 = 1.06 mm
D84 = 1.5 mm
SIGMA = .22
FALL RIVER S-C SECTION 1 LEFT BANK
JULY 3,1984 STAGE = 1.49 ft
D16 = .451 mm
D50 = .84 mm
D65 = 1.05 mm
D84 = 1.3 mm
SIGMA = .31
PERCENTAGE FINER
SIEVE SIZE, mm

Figure 5. (continued)

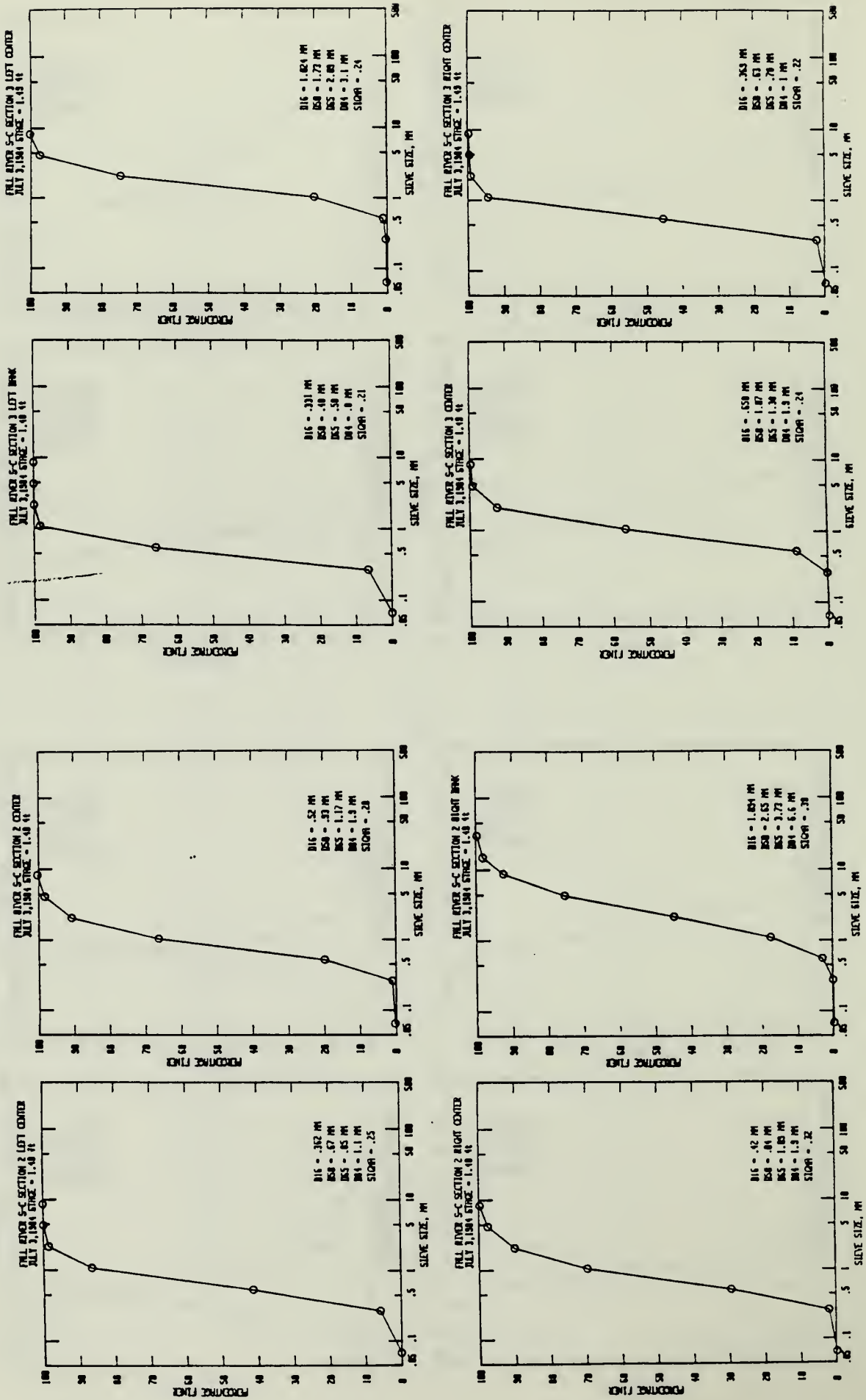

FALL RIVER S-C SECTION 3 LEFT CENTER
JULY 3,1984 STAGE = 1.43 ft
D16 = 1.824 MM
D50 = 1.73 MM
D65 = 2.83 MM
D84 = 3.1 MM
SIGM = .24
FALL RIVER S-C SECTION 3 LEFT BANK
JULY 3,1984 STAGE = 1.40 ft
D16 = .331 MM
D50 = .48 MM
D65 = .58 MM
D84 = .8 MM
SIGM = .21
FALL RIVER S-C SECTION 3 RIGHT CENTER
JULY 3,1984 STAGE = 1.43 ft
D16 = .363 MM
D50 = .63 MM
D65 = .78 MM
D84 = 1 MM
SIGM = .22
FALL RIVER S-C SECTION 3 CENTER
JULY 3,1984 STAGE = 1.40 ft
D16 = .658 MM
D50 = 1.07 MM
D65 = 1.38 MM
D84 = 1.8 MM
SIGM = .24
FALL RIVER S-C SECTION 2 CENTER
JULY 3,1984 STAGE = 1.40 ft
D16 = .52 MM
D50 = .93 MM
D65 = 1.17 MM
D84 = 1.8 MM
SIGM = .28
FALL RIVER S-C SECTION 2 RIGHT BANK
JULY 3,1984 STAGE = 1.40 ft
D16 = 1.824 MM
D50 = 2.65 MM
D65 = 3.73 MM
D84 = 6.6 MM
SIGM = .38
FALL RIVER S-C SECTION 2 LEFT CENTER
JULY 3,1984 STAGE = 1.40 ft
D16 = .382 MM
D50 = .67 MM
D65 = .85 MM
D84 = 1.1 MM
SIGM = .25
FALL RIVER S-C SECTION 2 RIGHT CENTER
JULY 3,1984 STAGE = 1.40 ft
D16 = .42 MM
D50 = .84 MM
D65 = 1.05 MM
D84 = 1.3 MM
SIGM = .32
SIEVE SIZE, MM
PERCENTAGE FINER

Figure 5. (continued)

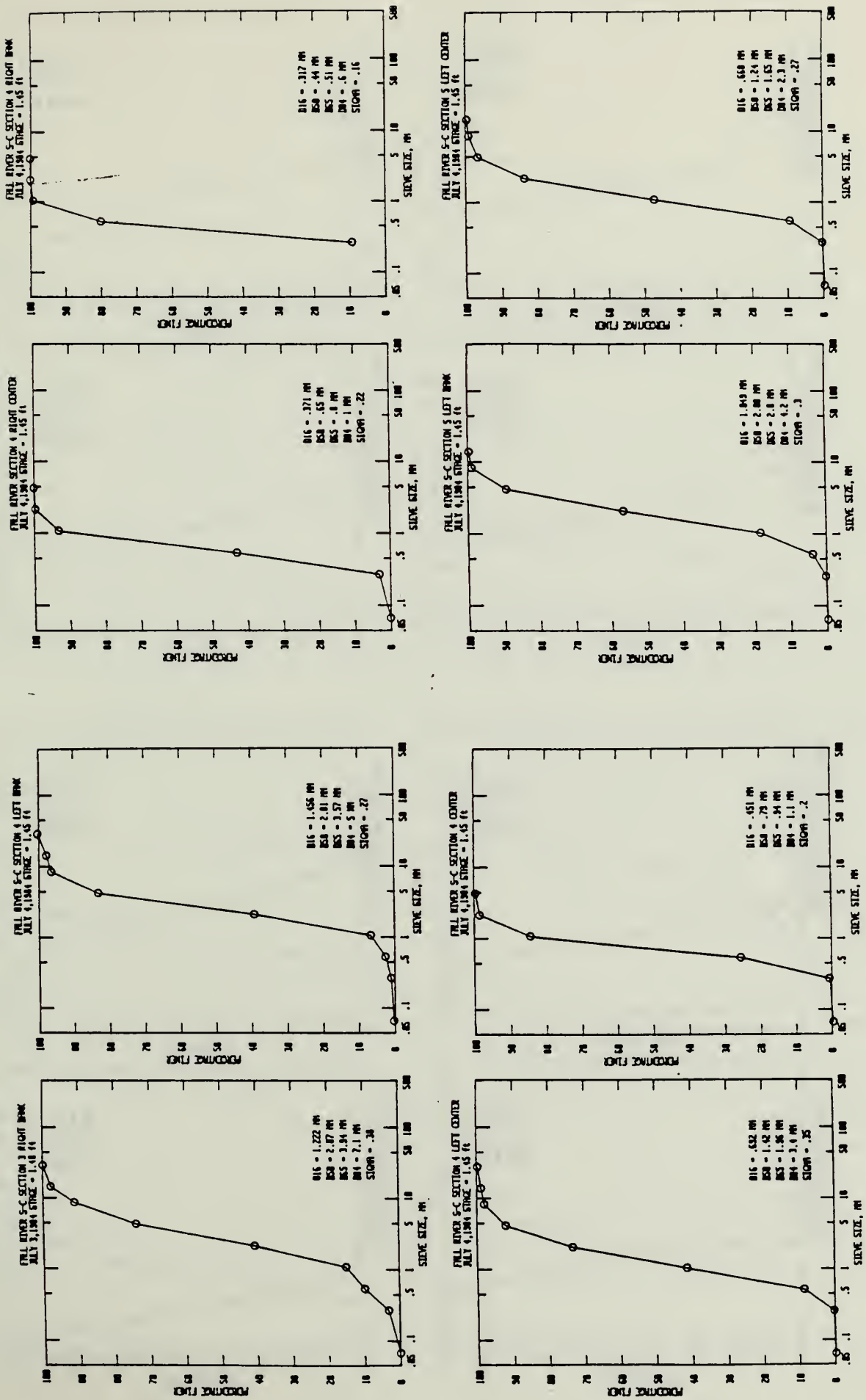

FALL RIVER S-C SECTION 4 RIGHT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = .317 mm
D50 = .44 mm
D65 = .51 mm
D84 = .6 mm
SIGM = .16
FALL RIVER S-C SECTION 4 RIGHT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .371 mm
D50 = .65 mm
D65 = .8 mm
D84 = 1 mm
SIGM = .22
FALL RIVER S-C SECTION 5 LEFT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .668 mm
D50 = 1.24 mm
D65 = 1.63 mm
D84 = 2.3 mm
SIGM = .27
FALL RIVER S-C SECTION 5 LEFT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = 1.049 mm
D50 = 2.08 mm
D65 = 2.8 mm
D84 = 4.2 mm
SIGM = .3
FALL RIVER S-C SECTION 3 RIGHT BANK
JULY 3,1984 STAGE = 1.18 ft
D16 = 1.222 mm
D50 = 2.47 mm
D65 = 3.34 mm
D84 = 7.1 mm
SIGM = .38
FALL RIVER S-C SECTION 4 LEFT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = 1.456 mm
D50 = 2.81 mm
D65 = 3.57 mm
D84 = 5 mm
SIGM = .27
FALL RIVER S-C SECTION 4 CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .451 mm
D50 = .73 mm
D65 = .94 mm
D84 = 1.1 mm
SIGM = .2
FALL RIVER S-C SECTION 4 LEFT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .582 mm
D50 = 1.42 mm
D65 = 1.96 mm
D84 = 3.4 mm
SIGM = .35
PERCENTAGE FINER
SIEVE SIZE, mm

Figure 5. (continued)

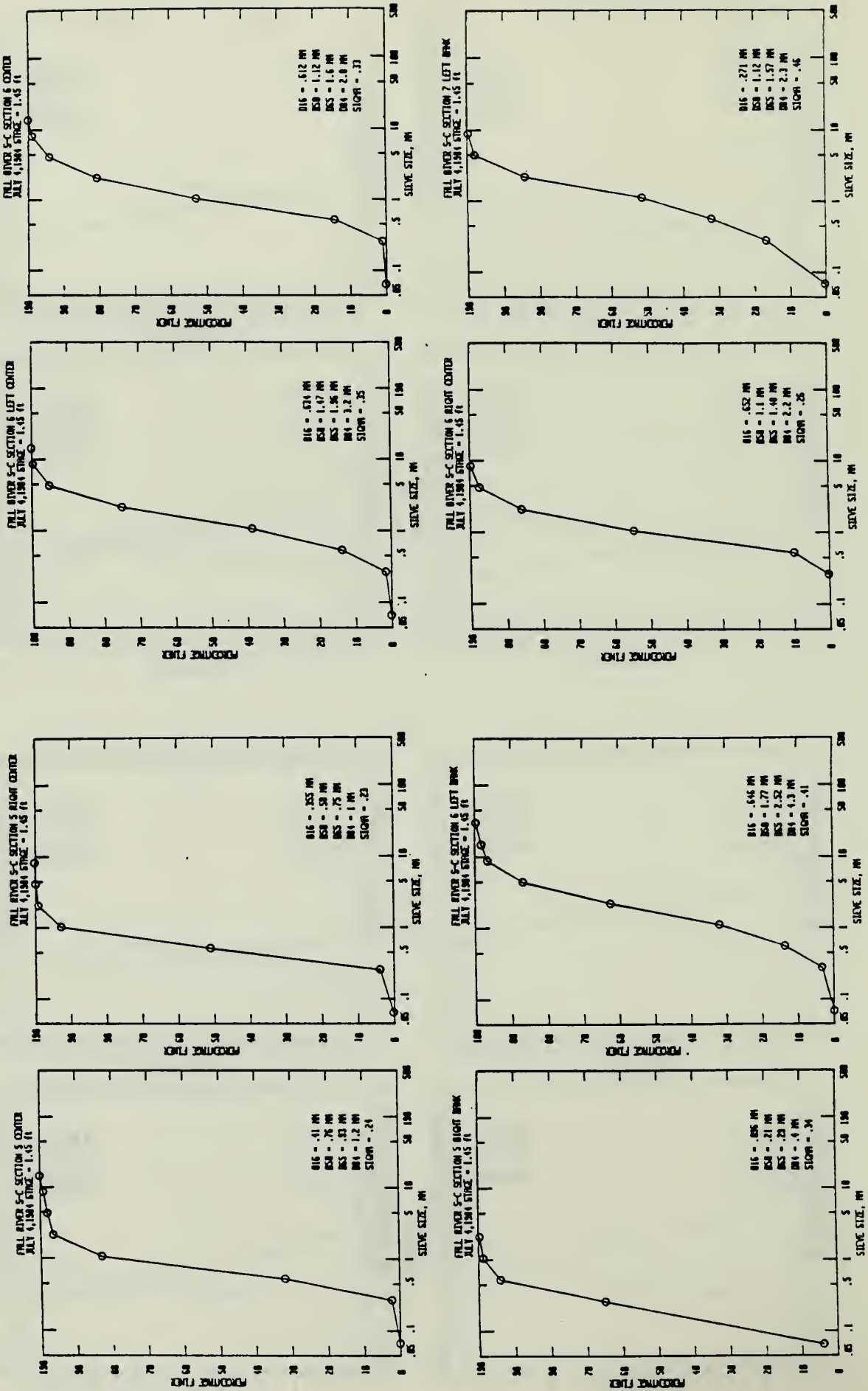

FALL RIVER S-C SECTION 6 CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .612 MM
D50 = 1.12 MM
D65 = 1.6 MM
D84 = 2.8 MM
SIGM = .33
FALL RIVER S-C SECTION 6 LEFT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .614 MM
D50 = 1.47 MM
D65 = 1.96 MM
D84 = 3.2 MM
SIGM = .35
FALL RIVER S-C SECTION 7 LEFT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = .271 MM
D50 = 1.12 MM
D65 = 1.57 MM
D84 = 2.3 MM
SIGM = .46
FALL RIVER S-C SECTION 6 RIGHT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .652 MM
D50 = 1.1 MM
D65 = 1.49 MM
D84 = 2.2 MM
SIGM = .26
FALL RIVER S-C SECTION 5 RIGHT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .353 MM
D50 = .98 MM
D65 = .75 MM
D84 = 1 MM
SIGM = .23
FALL RIVER S-C SECTION 6 LEFT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = .646 MM
D50 = 1.77 MM
D65 = 2.52 MM
D84 = 4.3 MM
SIGM = .41
FALL RIVER S-C SECTION 5 CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .41 MM
D50 = .76 MM
D65 = .53 MM
D84 = 1.2 MM
SIGM = .24
FALL RIVER S-C SECTION 5 RIGHT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = .856 MM
D50 = .21 MM
D65 = .29 MM
D84 = .4 MM
SIGM = .34
PERCENTAGE FINER
SIEVE SIZE, MM

Figure 5. (continued)

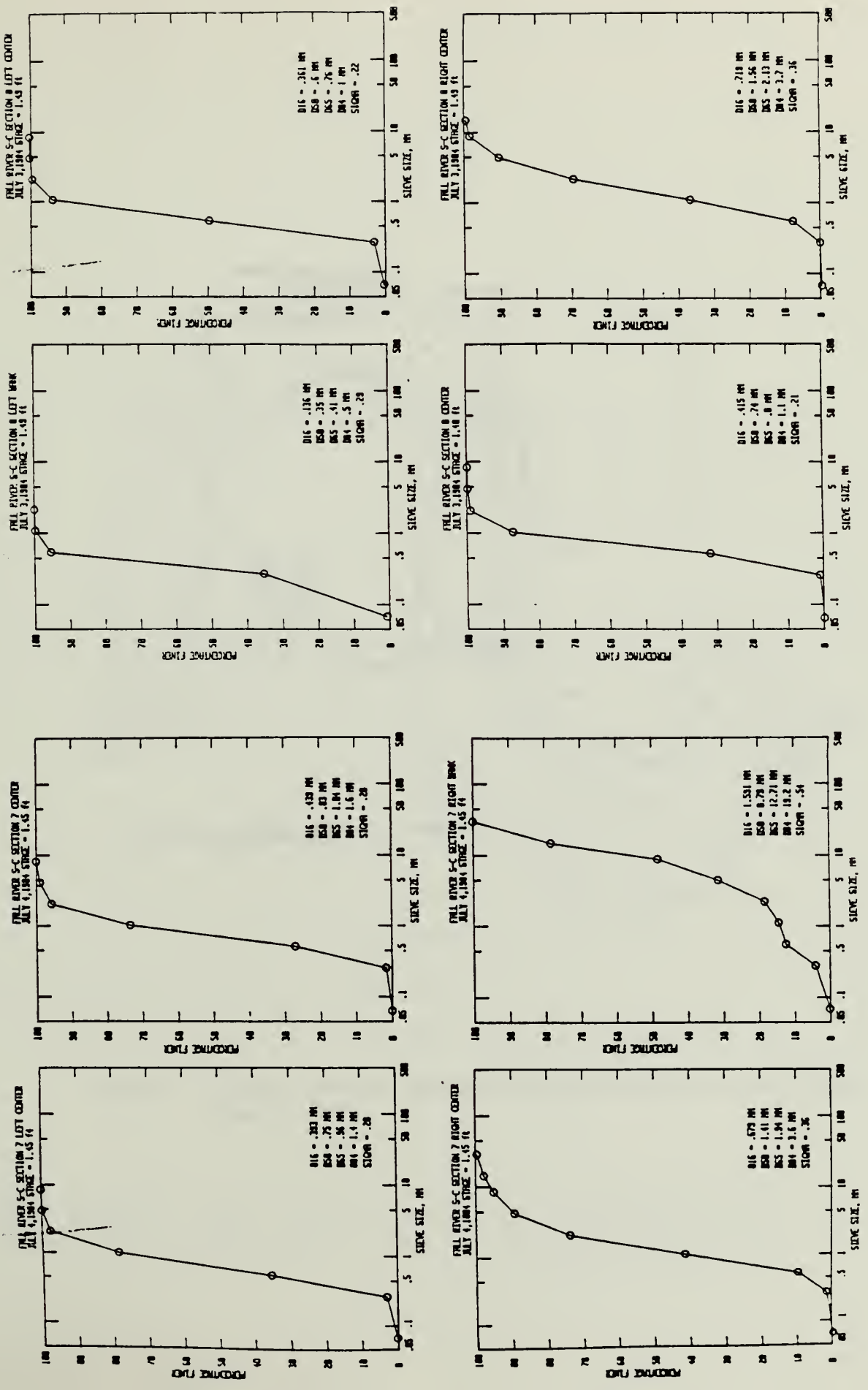

FALL RIVER S-C SECTION 8 LEFT CENTER
JULY 3,1984 STAGE = 1.43 ft
D16 = .361 mm
D50 = .6 mm
D65 = .76 mm
D84 = 1 mm
SIGM = .22
FALL RIVER S-C SECTION 8 RIGHT CENTER
JULY 3,1984 STAGE = 1.43 ft
D16 = .719 mm
D50 = 1.56 mm
D65 = 2.13 mm
D84 = 3.7 mm
SIGM = .36
FALL RIVER S-C SECTION 8 LEFT BANK
JULY 3,1984 STAGE = 1.43 ft
D16 = .136 mm
D50 = .35 mm
D65 = .41 mm
D84 = .5 mm
SIGM = .23
FALL RIVER S-C SECTION 8 CENTER
JULY 3,1984 STAGE = 1.18 ft
D16 = .415 mm
D50 = .74 mm
D65 = .8 mm
D84 = 1.1 mm
SIGM = .21
FALL RIVER S-C SECTION 7 CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .439 mm
D50 = .83 mm
D65 = 1.04 mm
D84 = 1.5 mm
SIGM = .28
FALL RIVER S-C SECTION 7 RIGHT BANK
JULY 4,1984 STAGE = 1.45 ft
D16 = 1.531 mm
D50 = 8.79 mm
D65 = 12.71 mm
D84 = 19.2 mm
SIGM = .54
FALL RIVER S-C SECTION 7 LEFT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .353 mm
D50 = .75 mm
D65 = .96 mm
D84 = 1.4 mm
SIGM = .28
FALL RIVER S-C SECTION 7 RIGHT CENTER
JULY 4,1984 STAGE = 1.45 ft
D16 = .673 mm
D50 = 1.41 mm
D65 = 1.84 mm
D84 = 3.6 mm
SIGM = .36
PERCENTAGE FINER
SIEVE SIZE, mm

Figure 5. (continued)

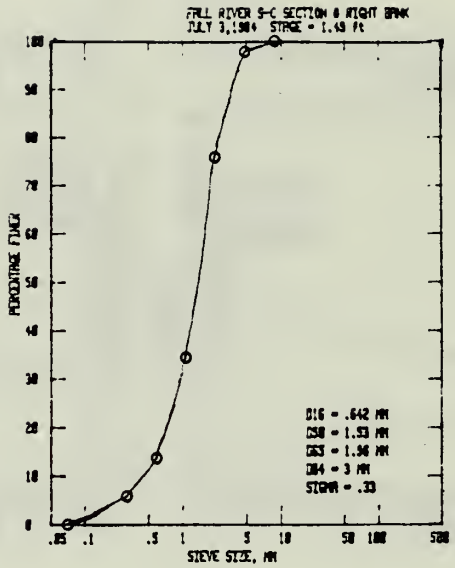


Figure 5. (continued)

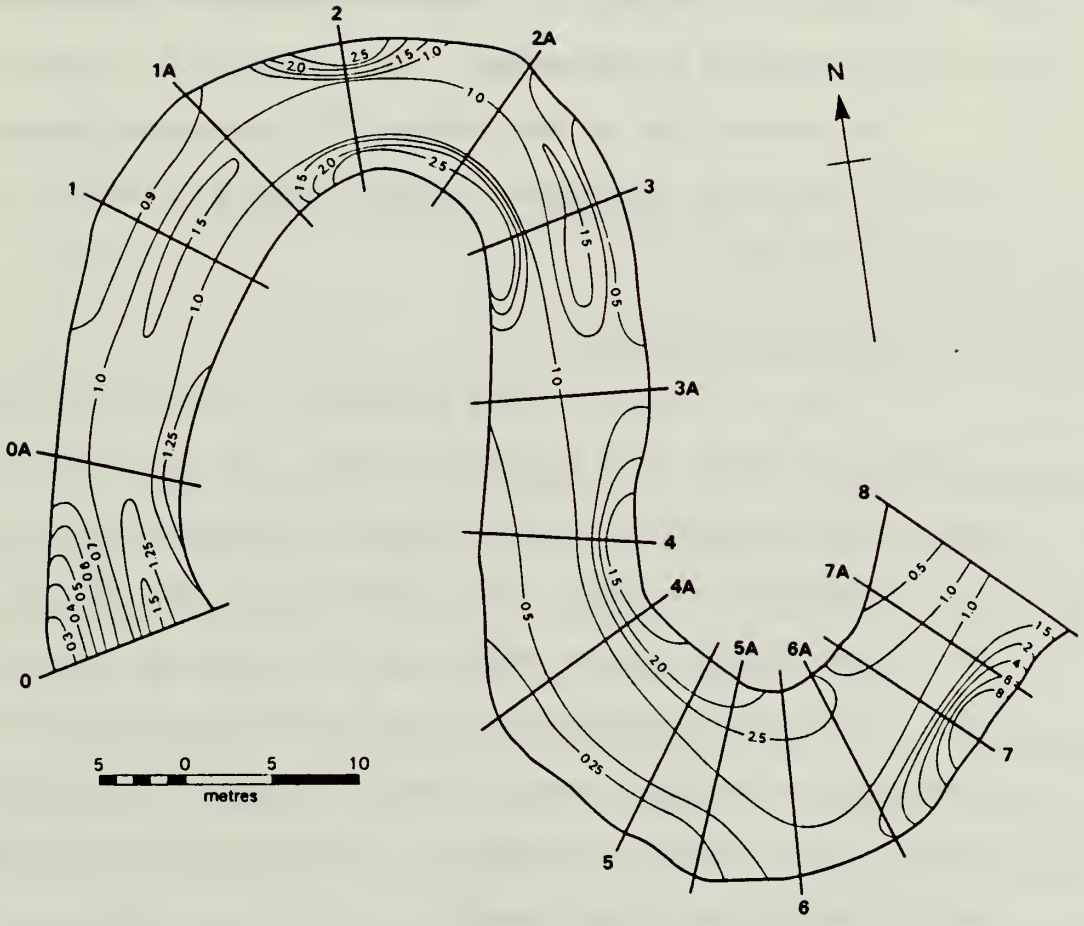


Figure 6. Distribution of Median Bed Material Size in Study Reach, July 3, 1984

Bed Load Transport Rate

Bed load transport rate was estimated from the Helley-Smith sampling of John Pitlick* at the Fall River sediment sampling site #2 (FR2) just downstream of te study reach (Fig. 1). The data for July 3-6, 1984 indicate an average bed load transport rate in the region of 1.5 kg/s (3.3 lb/sec). A realistic confidence interval for this bed load figure would be ±50 percent.

The median size of bed load at FR2 during the study period was about 1 mm, which corresponds to the median bed material size in the study reach (Fig. 6).

Two-Dimensional Velocities

x and y velocities were measured at 17 sections around the two consecutive bends, from temporary bridges. At each section the bridge was oriented normal to the outer bank and approximately orthogonal to the longstream direction. The current meter was set up to measure velocities normal to the bridge (x) and along the line of the bridge (y). These were longstream (x) and cross-stream (y) velocities, with reference to the local channel direction. These are not necessarily the primary and secondary components of velocity because the primary flow may be skewed across the channel.

To account for this and to make the presentation of the results as objective as possible, the resultant velocity vector at each point was

*Pitlick, J. C., 1984, "Sediment Transport and Channel Modifications of the Fall River following the Lawn Lake Flood." Thesis submitted in partial fulfillment of the degree M.S., Colorado State University, Fort Collins, Colorado.

resolved into its primary and secondary components using a method proposed by Dietrich and Smith.*

In this method the net secondary discharge at a section (found by integrating the secondary velocity over the depth) is compared to that required by continuity between the sections immediately upstream and downstream. If the two differ, the section is reoriented to change the secondary velocities until agreement is reached. The angles of reorientation are listed in Table 3.

Table 3. Angles of Reorientation of Sections

Section	0A	1	1A	2	2A	3	3A	4	4A	5	5A	6	6A	7	7A
Angle	-9	1.4	0	-1.5	3.5	-3.5	1.1	-1.8	-16	-5.4	6.8	-13.7	0.5	9.6	-5.6

(Positive angles indicate counterclockwise rotation.)

Reorienting the sections changed the y velocities significantly, although it did not radically alter the secondary flow patterns. The reorienting procedure cannot be applied at Section 0 (which has no upstream section) or 8 (which has no downstream section).

Both the x-y (long stream-cross-stream), and x'-y' (primary and secondary) velocities are listed in Table 4. Primary isovels and secondary velocities are presented in Fig. 7. The longstream and cross-stream velocities for Sections 0 and 8 are listed in Table 5, and the isovels are displayed in Fig. 8.

*Dietrich, W. E. and Smith, J. D., 1983, "Influence of the Point Bar on Flow in Curved Channels." Water Resources Research, paper 3W1080, Vol. 19, No. 4, October, pp. 1173-1192.

Table 4. x-y and Primary-Secondary Velocities for Sections 0A-7A

SECTION 0A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
0	1.20					
0.6	1.26	0.09	0.63	0.04	0.62	0.14
		0.15	0.71	-0.10	0.72	0.01
		0.45	0.75	-0.03	0.74	0.09
		0.75	0.70	0.04	0.68	0.15
		1.05	0.62	-0.10	0.62	0
		1.23	0.59	-0.17	0.61	-0.07
	Depth Averaged Values:		0.68	-0.04	0.68	0.07
1.2	1.26	0.09	0.53	-0.09	0.54	-0.01
		0.15	0.72	-0.15	0.73	-0.03
		0.45	0.79	0.08	0.77	0.21
		0.75	0.80	0.06	0.78	0.18
		1.05	0.75	-0.06	0.75	0.06
		1.23	0.68	-0.21	0.71	-0.10
	Depth Averaged Values:		0.74	-0.03	0.74	0.09
1.8	1.14	0.09	0.80	-0.05	0.80	0.08
		0.15	0.79	0.04	0.78	0.16
		0.45	0.80	0.01	0.79	0.13
		0.75	0.77	-0.06	0.77	0.07
		0.93	0.77	-0.10	0.78	0.02
		1.11	0.75	-0.29	0.78	-0.17
	Depth Averaged Values:		0.78	-0.06	0.78	0.07
2.4	1.11	0.09	0.52	-0.06	0.52	0.03
		0.15	0.68	-0.20	0.70	-0.09
		0.45	0.77	-0.12	0.78	0
		0.75	0.79	-0.03	0.79	0.10
		0.90	0.83	-0.07	0.83	0.06
		1.08	0.71	-0.24	0.74	-0.13
	Depth Averaged Values:		0.73	-0.11	0.74	0
3	0.99	0.09	0.59	-0.25	0.62	-0.15
		0.15	0.68	-0.17	0.70	-0.07
		0.45	0.75	-0.14	0.77	-0.02
		0.75	0.75	0	0.75	0.12
		0.96	0.76	-0.04	0.76	0.08
	Depth Averaged Values:		0.72	-0.11	0.73	0

Table 4. (continued)

SECTION 0A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
3.6	0.99	0.09	0.35	-0.22	0.38	-0.16
		0.15	0.53	-0.20	0.56	-0.12
		0.45	0.76	-0.17	0.78	-0.05
		0.75	0.75	-0.07	0.75	0.04
		0.96	0.74	-0.12	0.75	0
	Depth Averaged Values:		0.66	-0.15	0.68	-0.05
4.2	0.75	0.09	0.61	-0.17	0.63	-0.07
		0.15	0.58	-0.13	0.59	-0.04
		0.45	0.70	-0.17	0.72	-0.06
		0.72	0.73	-0.04	0.72	0.08
	Depth Averaged Values:		0.66	-0.13	0.67	-0.03
4.8	0.57	0.09	0.52	-0.30	0.57	-0.22
		0.15	0.53	-0.23	0.56	-0.14
		0.33	0.65	-0.14	0.67	-0.03
		0.54	0.65	-0.07	0.66	0.03
	Depth Averaged Values:		0.60	-0.18	0.62	-0.08
5.4	0.36	0.09	0.54	-0.13	0.56	-0.04
		0.15	0.55	-0.05	0.55	-0.04
		0.33	0.61	-0.09	0.61	0
	Depth Averaged Values:		0.57	-0.09	0.57	0
6	0.36	0.09	0.56	-0.24	0.59	-0.15
		0.15	0.52	-0.17	0.53	-0.08
		0.33	0.55	-0.08	0.56	0
	Depth Averaged Values:		0.54	-0.16	0.56	-0.08
7.2	0.30					

Table 4. (continued)

SECTION 1

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.6	0.96	0.09	0.08	-0.07	0.07	-0.07
		0.15	0.21	-0.06	0.21	-0.06
		0.45	0.42	0.03	0.42	0.02
		0.75	0.41	0.04	0.41	0.03
		0.93	0.39	-0.01	0.39	-0.02
	Depth Averaged Values:		0.33	0	0.33	-0.01
1.2	0.84	0.09	0.49	0.07	0.50	0.05
		0.15	0.47	0.06	0.47	0.05
		0.45	0.60	0.09	0.60	0.07
		0.81	0.50	-0.01	0.50	-0.02
	Depth Averaged Values:		0.53	0.06	0.53	0.04
1.8	0.81	0.09	0.48	-0.10	0.47	-0.12
		0.15	0.50	0	0.50	-0.01
		0.45	0.70	0.10	0.71	0.09
		0.78	0.58	0.02	0.58	0
	Depth Averaged Values:		0.59	0.03	0.60	0.02
2.4	0.78	0.09	0.45	0.11	0.45	0.10
		0.15	0.59	0.08	0.59	0.06
		0.45	0.73	0.10	0.73	0.08
		0.75	0.62	0.03	0.62	0.01
	Depth Averaged Values:		0.63	0.08	0.63	0.06
3	0.69	0.09	0.66	0.10	0.66	0.08
		0.15	0.69	0.09	0.70	0.07
		0.45	0.79	0.04	0.79	0.02
		0.66	0.67	0.01	0.67	-0.01
	Depth Averaged Values:		0.72	0.06	0.72	0.04
3.6	0.69	0.09	0.67	0.07	0.68	0.05
		0.15	0.81	0.01	0.81	-0.01
		0.39	0.84	0.02	0.84	0
		0.54	0.79	-0.03	0.79	-0.05
		0.66	0.75	0	0.75	-0.02
	Depth Averaged Values:		0.78	0.01	0.78	-0.01
4.2	0.66	0.09	0.74	0.05	0.74	0.03
		0.15	0.71	-0.02	0.71	-0.04
		0.39	0.79	-0.07	0.79	-0.09
		0.54	0.79	-0.04	0.79	-0.06
		0.63	0.75	-0.05	0.75	-0.07
	Depth Averaged Values:		0.76	-0.03	0.76	-0.05

Table 4. (continued)

SECTION 1

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
4.8	0.72	0.09	0.75	-0.09	0.75	-0.10
		0.15	0.79	-0.07	0.79	-0.09
		0.39	0.83	-0.05	0.83	-0.07
		0.54	0.81	-0.09	0.81	-0.11
		0.69	0.75	-0.12	0.75	-0.14
	Depth Averaged Values:		0.79	-0.08	0.79	-0.01
5.4	0.72	0.09	0.69	-0.04	0.69	-0.05
		0.15	0.76	-0.18	0.76	-0.20
		0.39	0.82	-0.06	0.82	-0.08
		0.54	0.80	-0.08	0.80	-0.10
		0.69	0.73	-0.07	0.73	-0.08
	Depth Averaged Values:		0.77	-0.09	0.77	-0.01
6	0.69	0.09	0.72	-0.12	0.72	-0.14
		0.15	0.62	-0.14	0.61	-0.16
		0.39	0.81	-0.08	0.81	-0.10
		0.66	0.77	-0.09	0.77	-0.11
	Depth Averaged Values:		0.74	-0.10	0.74	-0.12
6.6	0.69	0.09	0.42	0.06	0.42	0.05
		0.15	0.39	-0.03	0.39	-0.04
		0.39	0.64	-0.06	0.63	-0.07
		0.66	0.75	-0.11	0.75	-0.13
	Depth Averaged Values:		0.57	-0.04	0.57	-0.06
7.2	0.69	0.09	0.52	0.07	0.52	0.05
		0.15	0.62	-0.01	0.62	-0.02
		0.39	0.74	-0.14	0.74	-0.16
		0.66	0.70	-0.14	0.70	-0.16
	Depth Averaged Values:		0.67	-0.08	0.67	-0.09
7.8	0.66	0.09	0.53	-0.06	0.53	-0.07
		0.15	0.54	-0.12	0.54	-0.14
		0.39	0.65	-0.11	0.64	-0.13
		0.63	0.69	-0.09	0.69	-0.11
	Depth Averaged Values:		0.61	-0.10	0.61	-0.12
8.4	0.60	0.09	0.48	-0.08	0.47	-0.09
		0.15	0.51	-0.07	0.51	-0.08
		0.36	0.59	-0.09	0.59	-0.11
		0.57	0.61	-0.11	0.61	-0.13
	Depth Averaged Values:		0.55	-0.09	0.55	-0.10
9.3	0.57					

Table 4. (continued)

SECTION 1A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.3	1.05					
0.6	1.20	0.09	0.25	-0.18	0.25	-0.18
		0.15	0.31	-0.09	0.31	-0.09
		0.45	0.51	-0.06	0.51	-0.06
		0.75	0.43	-0.02	0.43	-0.02
		0.96	0.45	-0.09	0.45	-0.09
		1.17	0.29	-0.18	0.29	-0.18
	Depth Averaged Values:		0.40	-0.09	0.40	-0.09
1.2	1.08	0.09	0.38	-0.15	0.38	-0.15
		0.15	0.46	-0.15	0.46	-0.15
		0.45	0.55	-0.04	0.55	-0.04
		0.75	0.57	0	0.57	0
		1.05	0.53	-0.11	0.53	-0.11
	Depth Averaged Values:		0.52	-0.07	0.52	-0.07
1.8	1.05	0.09	0.03	-0.09	0.03	-0.09
		0.15	-0.04	0.04	0.04	-0.04
		0.39	0.50	-0.06	0.50	-0.06
		0.54	0.67	-0.01	0.67	-0.01
		0.69	0.68	0	0.68	0
		0.84	0.70	0.05	0.70	0.05
		1.02	0.66	-0.01	0.66	-0.01
	Depth Averaged Values:		0.47	-0.01	0.48	-0.02
2.4	0.78	0.09	0.63	-0.08	0.63	-0.08
		0.15	0.65	-0.06	0.65	-0.06
		0.36	0.69	0.07	0.69	0.07
		0.51	0.76	0.06	0.76	0.06
		0.75	0.71	0.05	0.71	0.05
	Depth Averaged Values:		0.70	0.02	0.70	0.02
3	0.69	0.09	0.54	-0.05	0.54	-0.05
		0.15	0.58	-0.01	0.58	-0.01
		0.45	0.77	0.09	0.77	0.09
		0.66	0.74	0.04	0.74	0.04
	Depth Averaged Values:		0.67	0.03	0.67	0.03
3.6	0.57	0.09	0.60	0.03	0.60	0.03
		0.15	0.57	0.04	0.57	0.04
		0.36	0.71	0.10	0.71	0.10
		0.54	0.74	0.09	0.74	0.09
	Depth Averaged Values:		0.66	0.07	0.66	0.07

Table 4. (continued)

SECTION 1A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
4.2	0.51	0.09	0.69	0.08	0.69	0.08
		0.15	0.71	0.06	0.71	0.06
		0.30	0.80	0.10	0.80	0.10
		0.48	0.84	0.05	0.84	0.05
	Depth Averaged Values:		0.77	0.08	0.77	0.08
4.8	0.48	0.09	0.73	0.07	0.73	0.07
		0.15	0.77	0.01	0.77	0.01
		0.30	0.81	0.03	0.81	0.03
		0.45	0.82	0.06	0.82	0.06
	Depth Averaged Values:		0.78	0.04	0.78	0.04
5.4	0.51	0.09	0.44	0.07	0.44	0.07
		0.15	0.40	0.02	0.40	0.02
		0.30	0.78	-0.05	0.78	-0.05
		0.48	0.81	0.04	0.81	0.04
	Depth Averaged Values:		0.63	0.01	0.63	0.01
6	0.66	0.09	0.52	0.12	0.52	0.12
		0.15	0.49	0.04	0.49	0.04
		0.45	0.75	0.04	0.75	0.04
		0.63	0.71	0.10	0.71	0.09
	Depth Averaged Values:		0.63	0.07	0.63	0.06
6.6	0.54	0.09	0.69	0.05	0.69	0.05
		0.15	0.74	0.10	0.74	0.10
		0.33	0.78	-0.08	0.78	-0.08
		0.51	0.76	0.03	0.76	0.03
	Depth Averaged Values:		0.75	0.01	0.75	0.01
7.2	0.63	0.09	0.55	0.07	0.55	0.07
		0.15	0.62	0.05	0.62	0.05
		0.36	0.74	0.10	0.74	0.10
		0.60	0.76	0.06	0.76	0.06
	Depth Averaged Values:		0.68	0.07	0.68	0.07
7.8	0.60	0.09	0.65	0.12	0.65	0.12
		0.15	0.65	0.10	0.65	0.10
		0.36	0.68	0.09	0.68	0.09
		0.57	0.65	0.03	0.65	0.03
	Depth Averaged Values:		0.66	0.08	0.66	0.08
9	0.63	0.09	0.61	0.06	0.61	0.06
		0.15	0.65	0.08	0.65	0.08
		0.36	0.68	0.05	0.68	0.05
		0.60	0.61	0.04	0.61	0.04
	Depth Averaged Values:		0.64	0.06	0.64	0.06
9.6	0.60					

Table 4. (continued)

SECTION 2

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.6	0.42					
0.9	1.56					
1.2	1.56	0.09	0.63	-0.13	0.63	-0.12
		0.15	0.67	-0.15	0.67	-0.13
		0.45	0.71	0.01	0.71	0.03
		0.75	0.70	0.12	0.70	0.14
		1.05	0.59	0	0.59	0.02
		1.35	0.48	-0.15	0.48	-0.14
		1.53	0.39	-0.21	0.39	-0.20
	Depth Averaged Values:		0.61	-0.04	0.61	-0.02
1.5	1.59	0.09	0.68	-0.10	0.69	-0.09
		0.15	0.67	-0.26	0.68	-0.24
		0.45	0.71	-0.02	0.71	0
		0.60	0.67	0.03	0.67	0.05
		0.75	0.64	0.04	0.64	0.05
		1.05	0.60	-0.01	0.60	0.01
		1.20	0.44	-0.09	0.44	-0.08
		1.35	0.51	-0.09	0.52	-0.07
		1.56	0.41	-0.15	0.41	-0.14
	Depth Averaged Values:		0.60	-0.06	0.60	-0.05
2.1	1.59	0.09	0.64	-0.09	0.64	-0.08
		0.15	0.72	-0.13	0.73	-0.11
		0.45	0.70	-0.06	0.70	-0.04
		0.60	0.72	0.02	0.72	0.04
		0.75	0.69	0.05	0.69	0.07
		0.90	0.67	0.08	0.67	0.09
		1.05	0.68	0.03	0.68	0.05
		1.20	0.69	0.04	0.69	0.06
		1.35	0.70	0.01	0.70	0.03
		1.56	0.64	-0.04	0.64	-0.02
	Depth Averaged Values:		0.69	-0.01	0.69	0.01
2.4	1.35	0.09	0.63	-0.26	0.63	-0.24
		0.15	0.71	-0.21	0.72	-0.19
		0.45	0.69	-0.02	0.69	0
		0.75	0.70	0.08	0.71	0.09
		1.05	0.71	0.08	0.71	0.09
		1.32	0.67	0.24	0.67	0.26
	Depth Averaged Values:		0.69	0.01	0.69	0.02

Table 4. (continued)

SECTION 2

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
3	1.11	0.09	0.58	-0.09	0.58	-0.08
		0.15	0.57	-0.15	0.57	-0.14
		0.45	0.67	0.02	0.66	0.04
		0.75	0.72	0.11	0.72	0.13
		1.08	0.70	0.20	0.70	0.22
	Depth Averaged Values:		0.66	0.04	0.66	0.06
3.6	0.96	0.09	0.69	-0.07	0.70	-0.05
		0.15	0.65	-0.07	0.65	-0.05
		0.45	0.63	0.02	0.63	0.04
		0.75	0.70	0.24	0.70	0.26
		0.93	0.67	0.20	0.66	0.22
	Depth Averaged Values:		0.66	0.07	0.66	0.09
4.2	0.84	0.09	0.66	-0.18	0.66	-0.16
		0.15	0.64	-0.14	0.64	-0.13
		0.30	0.60	-0.10	0.60	0.11
		0.60	0.73	0.31	0.72	0.33
		0.81	0.71	0.30	0.70	0.32
	Depth Averaged Values:		0.67	0.13	0.67	0.14
4.8	0.69	0.09	0.56	-0.12	0.56	-0.11
		0.15	0.65	-0.01	0.65	0.01
		0.30	0.70	0.24	0.70	0.26
		0.45	0.77	0.39	0.76	0.41
		0.66	0.75	0.34	0.74	0.36
	Depth Averaged Values:		0.70	0.20	0.69	0.22
5.4	0.57	0.09	0.51	0.04	0.51	0.05
		0.15	0.59	0.12	0.59	0.14
		0.30	0.71	0.33	0.70	0.35
		0.54	0.71	0.33	0.70	0.35
	Depth Averaged Values:		0.64	0.21	0.63	0.23
6	0.42	0.09	0.80	0.34	0.79	0.36
		0.15	0.77	0.29	0.76	0.31
		0.30	0.72	0.25	0.72	0.27
		0.39	0.67	0.27	0.66	0.28
	Depth Averaged Values:		0.75	0.29	0.74	0.31
6.6	0.36	0.09	0.70	0.12	0.70	0.14
		0.15	0.75	0.22	0.74	0.24
		0.24	0.75	0.14	0.75	0.16
		0.33	0.67	0.10	0.66	0.11
	Depth Averaged Values:		0.72	0.14	0.71	0.16
7.2	0.18					

Table 4. (continued)

SECTION 2A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
0.3	1.26	0.09	0.22	-0.31	0.20	-0.32
		0.15	0.24	-0.20	0.23	-0.21
		0.45	0.41	0.01	0.41	-0.01
		0.75	0.45	0.02	0.45	-0.01
		1.02	0.44	0.02	0.44	-0.01
		1.23	0.32	0	0.32	-0.02
	Depth Averaged Values:		0.37	-0.05	0.37	-0.07
0.6	1.35	0.09	0.20	-0.33	0.18	-0.34
		0.15	0.17	-0.32	0.15	-0.33
		0.45	0.40	0.02	0.40	0
		0.75	0.58	0.14	0.59	0.10
		1.05	0.59	0.07	0.60	0.04
		1.32	0.63	0.14	0.64	0.10
	Depth Averaged Values:		0.46	0	0.46	-0.03
1.2	1.26	0.09	0.29	-0.18	0.28	-0.19
		0.15	0.38	-0.03	0.38	-0.05
		0.45	0.55	0.06	0.55	0.03
		0.75	0.74	0.21	0.75	0.16
		1.05	0.73	0.22	0.74	0.17
		1.26	0.73	0.19	0.74	0.14
	Depth Averaged Values:		0.60	0.11	0.61	0.07
1.8	1.44	0.09	0.21	-0.08	0.20	-0.10
		0.15	0.25	-0.03	0.25	-0.05
		0.45	0.51	0.01	0.51	-0.02
		0.75	0.76	0.07	0.76	0.03
		1.05	0.77	0.16	0.78	0.11
		1.26	0.72	0.24	0.73	0.19
	Depth Averaged Values:		0.59	0.08	0.60	0.04
2.4	1.26	0.09	0.73	-0.12	0.72	-0.17
		0.15	0.78	-0.11	0.77	-0.16
		0.45	0.78	0.03	0.78	-0.02
		0.75	0.80	0.23	0.81	0.18
		1.05	0.75	0.26	0.76	0.21
		1.23	0.69	0.31	0.70	0.27
	Depth Averaged Values:		0.77	0.11	0.77	0.06
3	1.08	0.09	0.86	-0.09	0.86	-0.15
		0.15	0.87	-0.11	0.86	-0.17
		0.45	0.84	0.07	0.85	0.02
		0.75	0.78	0.20	0.79	0.15
		1.05	0.72	0.27	0.73	0.23
	Depth Averaged Values:		0.81	0.09	0.82	0.04

Table 4. (continued)

SECTION 2A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
3.6	0.99	0.09	0.58	-0.22	0.57	-0.25
		0.15	0.90	-0.16	0.89	-0.21
		0.45	0.87	0.01	0.87	-0.04
		0.69	0.80	0.16	0.81	0.11
		0.96	0.74	0.20	0.75	0.15
	Depth Averaged Values:		0.80	0.02	0.80	-0.03
4.2	0.75	0.09	0.61	-0.07	0.61	-0.11
		0.15	0.80	-0.09	0.79	-0.14
		0.45	0.82	0.06	0.82	0.01
		0.72	0.76	0.16	0.77	0.11
	Depth Averaged Values:		0.77	0.03	0.77	-0.02
4.8	0.60	0.09	0.38	-0.05	0.38	-0.08
		0.15	0.54	-0.05	0.54	-0.08
		0.45	0.77	0.16	0.78	0.11
		0.57	0.69	0.17	0.70	0.12
	Depth Averaged Values:		0.61	0.06	0.62	0.02
5.4	0.57	0.09	0.62	0.01	0.62	-0.03
		0.15	0.67	0.05	0.67	0.01
		0.36	0.64	0.06	0.65	0.02
		0.54	0.59	0.10	0.60	0.07
	Depth Averaged Values:		0.63	0.06	0.64	0.02
6	0.36	0.09	0.57	-0.02	0.57	-0.06
		0.15	0.57	-0.01	0.57	-0.05
		0.30	0.67	0.03	0.67	-0.01
		0.33	0.69	-0.02	0.68	-0.06
	Depth Averaged Values:		0.61	0	0.61	-0.04
6.6	0.27	0.09	0.61	-0.11	0.61	-0.15
		0.15	0.61	-0.02	0.61	-0.06
		0.21	0.64	0.01	0.64	-0.03
		0.24	0.64	0	0.64	-0.04
	Depth Averaged Values:		0.62	-0.05	0.62	-0.09
7.2	0.21	0.09	0.53	-0.06	0.53	-0.09
		0.18	0.59	-0.04	0.59	-0.08
	Depth Averaged Values:		0.55	-0.05	0.55	-0.09
7.8	0.15					

Table 4. (continued)

SECTION 3

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
0.3	0.09					
0.6	1.14	0.09	0.41	0.07	0.40	0.10
		0.15	0.47	0.14	0.46	0.17
		0.45	0.43	0.12	0.42	0.15
		0.75	0.46	-0.03	0.46	0
		0.90	0.55	-0.02	0.55	0.01
		1.11	0.51	-0.09	0.51	-0.06
	Depth Averaged Values:		0.47	0.04	0.46	0.07
1.2	0.81	0.09	0.71	0.01	0.71	0.05
		0.15	0.72	0.09	0.72	0.14
		0.45	0.74	0.04	0.74	0.09
		0.78	0.65	-0.18	0.66	-0.14
	Depth Averaged Values:		0.71	-0.01	0.71	0.04
1.8	1.56	0.09	0.09	-0.01	0.09	0
		0.15	0.46	-0.25	0.47	-0.23
		0.45	0.74	-0.45	0.77	-0.40
		0.75	0.81	-0.16	0.81	-0.11
		1.05	0.81	-0.04	0.81	0.01
		1.35	0.84	0.12	0.83	0.17
		1.53	0.75	0.04	0.75	0.09
	Depth Averaged Values:		0.70	-0.13	0.71	-0.09
2.4	1.50	0.09	0.55	-0.32	0.57	-0.28
		0.15	0.55	-0.41	0.57	-0.37
		0.45	0.82	-0.05	0.82	0
		0.75	0.84	0.01	0.83	0.06
		1.05	0.86	0.11	0.85	0.16
		1.29	0.86	0.07	0.85	0.12
		1.47	0.81	0.12	0.80	0.17
	Depth Averaged Values:		0.78	-0.04	0.78	0
3	1.20	0.09	0.58	-0.40	0.60	-0.36
		0.15	0.62	-0.32	0.64	-0.28
		0.45	0.78	-0.03	0.78	0.02
		0.75	0.87	0.04	0.86	0.09
		0.99	0.84	0.20	0.82	0.25
		1.17	0.74	0.20	0.73	0.25
	Depth Averaged Values:		0.76	-0.03	0.76	0.02

Table 4. (continued)

SECTION 3

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
3.6	1.08	0.09	0.38	-0.32	0.40	-0.29
		0.15	0.50	-0.48	0.53	-0.45
		0.45	0.82	-0.20	0.83	-0.15
		0.60	0.81	-0.03	0.81	0.02
		0.75	0.79	0.03	0.78	0.08
		1.05	0.75	0.17	0.74	0.22
	Depth Averaged Values:		0.70	-0.13	0.70	-0.08
4.2	0.63	0.09	0.82	-0.14	0.82	-0.09
		0.15	0.83	-0.09	0.83	-0.04
		0.39	0.79	0.13	0.78	0.18
		0.60	0.75	0.18	0.74	0.23
	Depth Averaged Values:		0.80	0.04	0.79	0.09
4.8	0.60	0.09	0.62	-0.07	0.63	-0.03
		0.15	0.59	0	0.59	0.04
		0.39	0.69	0.17	0.68	0.22
		0.57	0.70	0.22	0.69	0.27
	Depth Averaged Values:		0.65	0.09	0.65	0.14
5.4	0.51	0.09	0.27	-0.13	0.27	-0.12
		0.15	0.30	0.01	0.29	0.03
		0.33	0.68	0.21	0.67	0.26
		0.48	0.71	0.22	0.70	0.27
	Depth Averaged Values:		0.50	0.09	0.49	0.12
6	0.45	0.09	0.24	-0.07	0.25	-0.06
		0.15	0.52	0.04	0.52	0.07
		0.30	0.70	0.19	0.69	0.24
		0.42	0.68	0.19	0.67	0.24
	Depth Averaged Values:		0.53	0.09	0.53	0.12
6.6	0.30	0.09	0.67	0.08	0.67	0.12
		0.15	0.71	0.10	0.71	0.15
		0.27	0.74	0.12	0.74	0.17
	Depth Averaged Values:		0.70	0.10	0.70	0.14
7.2	0.24	0.09	0.64	0.07	0.64	0.11
		0.15	0.64	0.04	0.64	0.08
		0.21	0.68	0.09	0.68	0.13
	Depth Averaged Values:		0.65	0.07	0.65	0.11
7.8	0.18					

Table 4. (continued)

SECTION 3A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
0.3	0.45					
0.6	0.93	0.09	0.12	-0.04	0.12	-0.04
		0.15	0.15	0.09	0.15	0.09
		0.45	0.81	0.15	0.81	0.14
		0.69	0.75	0.09	0.75	0.08
		0.90	0.64	-0.22	0.63	-0.23
	Depth Averaged Values:		0.55	0.05	0.55	0.04
1.2	0.84	0.09	0.88	-0.15	0.88	-0.17
		0.15	0.99	-0.11	0.99	-0.13
		0.45	0.97	-0.04	0.97	-0.06
		0.81	0.80	-0.14	0.80	-0.16
	Depth Averaged Values:		0.92	-0.10	0.92	-0.12
1.8	1.5	0.09	0.63	0.05	0.63	0.04
		0.15	0.44	-0.07	0.44	-0.08
		0.45	0.80	-0.08	0.80	-0.10
		0.75	0.95	-0.19	0.95	-0.21
		1.05	0.91	0	0.91	-0.02
		1.47	0.81	0.16	0.81	0.15
	Depth Averaged Values:		0.80	-0.03	0.80	-0.05
2.4	1.41	0.09	0.62	-0.30	0.61	-0.31
		0.15	0.66	-0.32	0.65	-0.34
		0.45	0.82	-0.27	0.81	-0.29
		0.75	0.91	-0.12	0.91	-0.14
		1.05	0.87	0.20	0.87	0.19
		1.17	0.82	0.22	0.82	0.21
		1.38	0.84	0.30	0.84	0.29
	Depth Averaged Values:		0.81	-0.07	0.81	-0.08
3	1.11	0.09	0.53	-0.21	0.52	-0.22
		0.15	0.57	-0.29	0.56	-0.30
		0.45	0.84	-0.14	0.84	-0.16
		0.75	0.77	0.13	0.77	0.12
		0.90	0.79	0.24	0.79	0.23
		1.08	0.72	0.27	0.72	0.26
	Depth Averaged Values:		0.73	-0.02	0.73	-0.03

Table 4. (continued)

SECTION 3A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
3.6	1.11	0.09	0.38	0	0.38	-0.01
		0.15	0.42	-0.07	0.42	-0.08
		0.45	0.72	-0.19	0.71	-0.21
		0.75	0.70	0.02	0.70	0.01
		0.90	0.72	0.06	0.72	0.05
		1.08	0.65	0.10	0.65	0.09
	Depth Averaged Values:		0.62	-0.04	0.62	-0.05
4.2	0.99	0.09	0.39	-0.03	0.39	-0.04
		0.15	0.56	-0.07	0.55	-0.08
		0.45	0.61	-0.05	0.60	-0.06
		0.75	0.59	0.03	0.59	0.02
		0.96	0.63	0.06	0.63	0.05
	Depth Averaged Values:		0.57	-0.02	0.57	-0.03
4.8	0.75	0.09	0.61	-0.03	0.61	-0.04
		0.15	0.63	0	0.63	-0.01
		0.45	0.67	0.06	0.67	0.05
		0.72	0.60	0.13	0.60	0.12
	Depth Averaged Values:		0.64	0.05	0.64	0.04
5.4	0.57	0.09	0.36	-0.01	0.36	0
		0.15	0.49	-0.03	0.49	-0.04
		0.33	0.52	0.09	0.52	0.08
		0.54	0.51	0.21	0.51	0.20
	Depth Averaged Values:		0.48	0.08	0.48	0.07
6	0.21	0.09	0.66	0.29	0.66	0.28
		0.18	0.64	0.18	0.64	0.17
	Depth Averaged Values:		0.65	0.25	0.65	0.24
6.6	0.15					
7.2	0.15					
7.8	0.06					

Table 4. (continued)

SECTION 4

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
0.3	0.75					
0.6	0.99	0.09	0.34	0.19	0.33	0.20
		0.15	0.36	0.16	0.35	0.17
		0.45	0.26	0.07	0.25	0.08
		0.75	0.08	0.04	0.08	0.04
		0.96	-0.09	-0.10	0.09	0.10
	Depth Averaged Values:		0.19	0.07	0.21	0.10
1.2	1.05	0.09	0.60	0.23	0.59	0.25
		0.15	0.67	0.22	0.67	0.25
		0.45	0.48	0.03	0.48	0.05
		0.75	0.32	0.01	0.32	0.02
		1.02	0.19	-0.03	0.19	-0.02
	Depth Averaged Values:		0.44	0.07	0.44	0.09
1.8	1.11	0.09	0.77	0.13	0.76	0.16
		0.15	0.82	0.14	0.81	0.17
		0.45	0.79	0.03	0.78	0.06
		0.75	0.74	0.02	0.74	0.04
		1.08	0.52	-0.08	0.52	-0.07
	Depth Averaged Values:		0.73	0.04	0.73	0.06
2.4	1.02	0.09	0.87	-0.05	0.87	-0.02
		0.15	0.89	-0.05	0.89	-0.02
		0.45	0.80	-0.10	0.80	-0.08
		0.75	0.82	0.05	0.81	0.08
		0.99	0.73	0.06	0.73	0.08
	Depth Averaged Values:		0.82	-0.02	0.82	0
3	0.96	0.09	0.58	-0.15	0.59	-0.13
		0.15	0.84	-0.13	0.84	-0.11
		0.45	0.86	-0.08	0.86	-0.05
		0.69	0.83	0.07	0.82	0.10
		0.93	0.74	0.15	0.74	0.18
	Depth Averaged Values:		0.79	-0.02	0.79	0
3.6	0.87	0.09	0.60	-0.01	0.60	0.01
		0.15	0.71	-0.12	0.72	-0.10
		0.45	0.88	-0.07	0.88	-0.04
		0.63	0.85	0	0.85	0.03
		0.84	0.75	0.05	0.75	0.07
	Depth Averaged Values:		0.78	-0.04	0.78	-0.01

Table 4. (continued)

SECTION 4

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
4.2	0.90	0.09	0.49	0.06	0.49	0.08
		0.15	0.65	0	0.65	0.02
		0.66	0.75	-0.07	0.76	-0.05
		0.78	0.83	-0.03	0.83	0
		0.87	0.77	-0.06	0.77	-0.04
	Depth Averaged Values:		0.69	-0.03	0.70	0
4.8	0.87	0.09	0.58	-0.02	0.58	0
		0.15	0.60	-0.02	0.60	0
		0.45	0.70	-0.06	0.71	-0.04
		0.66	0.79	-0.12	0.79	-0.10
		0.84	0.75	-0.10	0.76	-0.08
	Depth Averaged Values:		0.69	-0.07	0.69	-0.05
5.4	0.81	0.09	0.64	-0.09	0.65	-0.07
		0.15	0.67	-0.12	0.68	-0.10
		0.45	0.73	-0.06	0.74	-0.04
		0.60	0.79	-0.13	0.79	-0.11
		0.78	0.73	-0.09	0.74	-0.07
	Depth Averaged Values:		0.72	-0.10	0.72	-0.08
6	0.69	0.09	0.65	-0.12	0.65	0
		0.15	0.68	-0.02	0.68	0
		0.42	0.71	-0.09	0.72	-0.07
		0.66	0.70	-0.09	0.71	-0.07
	Depth Averaged Values:		0.69	-0.06	0.70	-0.04
6.6	0.69	0.09	0.44	0.04	0.44	0.05
		0.15	0.54	-0.04	0.54	-0.02
		0.45	0.64	-0.07	0.64	-0.05
		0.66	0.59	-0.01	0.59	0.01
	Depth Averaged Values:		0.57	-0.03	0.57	-0.01
7.2	0.69	0.09	0.30	0.10	0.29	0.11
		0.15	0.34	0.02	0.34	0.03
		0.45	0.42	-0.03	0.42	-0.02
		0.66	0.34	0.08	0.33	0.09
	Depth Averaged Values:		0.36	0.03	0.36	0.04
7.8	0.75					

Table 4. (continued)

SECTION 4A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.3	0.39					
0.6	0.75					
0.9	0.81					
1.2	0.81	0.09	0.54	0.01	0.52	0.16
		0.15	0.80	-0.08	0.79	0.14
		0.45	0.82	-0.07	0.81	0.16
		0.78	0.69	-0.10	0.69	0.09
	Depth Averaged Values:		0.74	-0.07	0.73	0.14
1.8	0.84	0.09	0.77	-0.14	0.78	0.08
		0.15	0.83	-0.12	0.83	0.11
		0.45	0.76	-0.20	0.79	0.02
		0.63	0.70	-0.21	0.73	-0.01
		0.81	0.61	-0.29	0.67	-0.11
	Depth Averaged Values:		0.74	-0.19	0.77	0.02
2.4	0.90	0.09	0.50	-0.12	0.51	0.02
		0.15	0.69	-0.31	0.75	-0.11
		0.45	0.82	-0.15	0.83	0.08
		0.69	0.80	-0.28	0.85	-0.05
		0.87	0.67	-0.28	0.72	-0.08
	Depth Averaged Values:		0.73	-0.23	0.76	-0.02
3	0.87	0.09	0.78	-0.16	0.79	0.06
		0.15	0.77	-0.26	0.81	-0.04
		0.45	0.92	-0.24	0.95	0.02
		0.66	0.88	-0.19	0.90	0.06
		0.84	0.84	-0.19	0.86	0.05
	Depth Averaged Values:		0.85	-0.21	0.88	0.03
3.6	0.87	0.09	0.61	-0.30	0.67	-0.12
		0.15	0.80	-0.28	0.85	-0.05
		0.45	0.84	-0.24	0.87	0
		0.66	0.84	-0.30	0.89	-0.06
		0.84	0.83	-0.16	0.84	0.07
	Depth Averaged Values:		0.80	-0.26	0.84	-0.03
4.2	0.84	0.09	0.52	-0.31	0.59	-0.15
		0.15	0.56	-0.22	0.60	-0.06
		0.45	0.72	-0.17	0.74	0.04
		0.81	0.79	-0.17	0.81	0.05
	Depth Averaged Values:		0.67	-0.20	0.71	-0.01

Table 4. (continued)

SECTION 4A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
4.8	0.90	0.09	0.56	-0.12	0.57	0.04
		0.15	0.56	-0.12	0.57	0.04
		0.45	0.69	-0.14	0.70	0.06
		0.87	0.75	-0.15	0.76	0.06
	Depth Averaged Values:		0.66	-0.14	0.67	0.05
5.4	0.90	0.09	0.58	-0.06	0.57	0.10
		0.15	0.58	-0.15	0.60	0.02
		0.45	0.73	-0.16	0.75	0.05
		0.69	0.77	-0.21	0.80	0.01
		0.87	0.69	-0.09	0.69	0.10
	Depth Averaged Values:		0.68	-0.15	0.70	0.05
6	0.99	0.09	0.60	-0.10	0.60	0.07
		0.15	0.63	-0.22	0.67	-0.04
		0.45	0.68	-0.18	0.70	0.01
		0.75	0.60	-0.16	0.62	0.01
		0.96	0.51	-0.07	0.51	0.07
	Depth Averaged Values:		0.62	-0.16	0.64	0.02
6.6	0.99	0.09	0.45	-0.17	0.48	-0.04
		0.15	0.43	-0.14	0.45	-0.02
		0.45	0.53	-0.15	0.55	0
		0.75	0.38	-0.05	0.38	0.06
		0.96	0.30	-0.04	0.30	0.04
	Depth Averaged Values:		0.43	-0.11	0.45	0.01
7.5	0.84	0.09	0.16	-0.13	0.19	-0.08
		0.15	0.13	-0.11	0.16	-0.07
		0.45	0.13	-0.05	0.14	-0.01
		0.81	0.04	-0.07	0.06	-0.06
	Depth Averaged Values:		0.11	-0.08	0.13	-0.05
8.4	0.42	0.09	-0.13	-0.04	0.11	0.07
		0.15	-0.11	-0.06	0.09	0.09
		0.39	-0.12	-0.06	0.10	0.09
	Depth Averaged Values:		-0.12	-0.05	0.10	0.08
9	0.18					
9.6	0.33					

Table 4. (continued)

SECTION 5

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.45	0.42					
0.75	0.45					
1.05	0.48					
1.2	0.51	0.09	0.67	-0.21	0.69	-0.14
		0.15	0.75	-0.22	0.77	-0.15
		0.33	0.78	-0.31	0.81	-0.24
		0.48	0.75	-0.25	0.77	-0.18
	Depth Averaged Values:		0.74	-0.25	0.76	-0.18
1.8	0.51	0.09	0.68	-0.28	0.71	-0.21
		0.15	0.75	-0.26	0.77	-0.18
		0.48	0.75	-0.31	0.78	-0.24
	Depth Averaged Values:		0.73	-0.28	0.76	-0.21
2.4	0.51	0.09	0.71	-0.34	0.74	-0.27
		0.15	0.77	-0.35	0.80	-0.28
		0.48	0.70	-0.33	0.73	-0.26
	Depth Averaged Values:		0.73	-0.34	0.76	-0.27
3	0.57	0.09	0.68	-0.24	0.70	-0.17
		0.15	0.67	-0.34	0.69	-0.28
		0.45	0.72	-0.50	0.77	-0.43
		0.54	0.67	-0.43	0.70	-0.36
	Depth Averaged Values:		0.69	-0.39	0.72	-0.32
3.6	0.75	0.09	0.52	-0.18	0.54	-0.13
		0.15	0.65	-0.20	0.66	-0.14
		0.45	0.74	-0.45	0.78	-0.37
		0.72	0.62	-0.44	0.66	-0.38
	Depth Averaged Values:		0.66	-0.34	0.69	-0.28
4.2	0.84	0.09	0.53	-0.05	0.53	0
		0.15	0.57	-0.16	0.58	-0.11
		0.45	0.69	-0.40	0.73	-0.33
		0.81	0.67	-0.40	0.71	-0.33
	Depth Averaged Values:		0.64	-0.30	0.66	-0.24
4.8	0.81	0.09	0.56	-0.20	0.58	-0.15
		0.15	0.59	-0.21	0.61	-0.15
		0.45	0.68	-0.43	0.72	-0.36
		0.78	0.70	-0.42	0.74	-0.35
	Depth Averaged Values:		0.65	-0.34	0.68	-0.28

Table 4. (continued)

SECTION 5

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
5.4	0.93	0.09	0.34	-0.10	0.35	-0.07
		0.15	0.39	-0.08	0.39	-0.04
		0.45	0.59	-0.37	0.62	-0.31
		0.75	0.65	-0.39	0.68	-0.33
		0.90	0.64	-0.38	0.67	-0.32
	Depth Averaged Values:		0.54	-0.29	0.56	-0.23
6	1.08	0.09	0.33	0	0.33	0.03
		0.15	0.45	-0.11	0.46	-0.07
		0.45	0.48	-0.23	0.50	-0.18
		0.75	0.60	-0.34	0.63	-0.28
		1.05	0.61	-0.38	0.64	-0.32
	Depth Averaged Values:		0.51	-0.24	0.53	-0.19
6.6	1.05	0.09	0.37	-0.06	0.37	-0.02
		0.15	0.40	-0.05	0.40	-0.01
		0.45	0.51	-0.25	0.53	-0.20
		0.75	0.52	-0.27	0.55	-0.22
		1.02	0.51	-0.26	0.53	-0.21
	Depth Averaged Values:		0.48	-0.20	0.49	-0.15
7.2	1.11	0.09	0.40	-0.09	0.41	-0.05
		0.15	0.45	-0.11	0.46	-0.07
		0.45	0.52	-0.23	0.54	-0.18
		0.75	0.51	-0.24	0.53	-0.19
	Depth Averaged Values:		0.47	-0.17	0.48	-0.13
7.8	1.17	0.09	0.21	0.07	0.20	0.09
		0.15	0.41	-0.05	0.41	-0.01
		0.45	0.45	-0.21	0.46	-0.17
		0.75	0.42	-0.23	0.44	-0.19
		1.14	0.32	0	0.32	0.03
	Depth Averaged Values:		0.39	-0.12	0.39	-0.09
8.4	1.11	0.09	0.23	0.06	0.22	0.08
		0.15	0.31	-0.09	0.32	-0.07
		0.45	0.39	-0.21	0.41	-0.17
		0.75	0.34	-0.14	0.35	-0.11
		1.08	0.24	0.04	0.23	0.06
	Depth Averaged Values:		0.32	-0.10	0.33	-0.07

Table 4. (continued)

SECTION 5

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
9	1.17	0.09	0.13	0.04	0.13	0.05
		0.15	0.20	-0.03	0.20	-0.01
		0.45	0.31	-0.13	0.32	-0.10
		0.75	0.31	-0.16	0.33	-0.13
		1.14	0.15	0.07	0.15	0.08
	Depth Averaged Values:		0.24	-0.07	0.25	-0.05
9.6	0.90	0.09	0.08	0.01	0.07	0.02
		0.15	0.10	-0.01	0.10	0
		0.45	0.17	0.01	0.17	0.03
		0.87	0.10	-0.06	0.10	-0.05
	Depth Averaged Values:		0.13	-0.01	0.12	0
10.05	0.72					
10.5	0.66					

Table 4. (continued)

SECTION 5A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
1.2	0.15					
1.8	0.15					
2.4	0.21	0.09	0.62	-0.29	0.58	-0.36
		0.18	0.62	-0.39	0.57	-0.46
	Depth Averaged Values:		0.62	-0.33	0.58	-0.40
3	0.21	0.09	0.56	-0.30	0.52	-0.37
		0.18	0.65	-0.43	0.59	-0.51
	Depth Averaged Values:		0.59	-0.35	0.54	-0.42
3.6	0.30	0.09	0.64	-0.34	0.59	-0.42
		0.15	0.67	-0.45	0.61	-0.53
		0.27	0.75	-0.50	0.68	-0.59
	Depth Averaged Values:		0.68	-0.42	0.62	-0.50
4.2	0.36	0.09	0.63	-0.26	0.59	-0.33
		0.15	0.64	-0.34	0.59	-0.42
		0.33	0.69	-0.42	0.63	-0.50
	Depth Averaged Values:		0.65	-0.34	0.60	-0.42
4.8	0.42	0.09	0.55	-0.21	0.52	-0.28
		0.15	0.60	-0.29	0.56	-0.36
		0.39	0.59	-0.40	0.53	-0.47
	Depth Averaged Values:		0.58	-0.31	0.54	-0.38
5.4	0.45	0.09	0.55	-0.29	0.51	-0.36
		0.15	0.64	-0.33	0.59	-0.41
		0.42	0.60	-0.40	0.54	-0.47
	Depth Averaged Values:		0.60	-0.34	0.55	-0.42
6	0.66	0.09	0.45	-0.11	0.44	-0.16
		0.15	0.58	-0.14	0.55	-0.21
		0.45	0.69	-0.37	0.64	-0.45
		0.63	0.68	-0.48	0.61	-0.56
	Depth Averaged Values:		0.61	-0.28	0.57	-0.35
6.6	0.84	0.09	0.12	-0.02	0.12	-0.03
		0.15	0.52	-0.07	0.50	-0.13
		0.45	0.52	-0.13	0.50	-0.19
		0.60	0.49	-0.20	0.47	-0.26
		0.81	0.58	-0.35	0.53	-0.42
	Depth Averaged Values:		0.47	-0.15	0.44	-0.21

Table 4. (continued)

SECTION 5A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
7.2	0.96	0.09	0.47	0.15	0.49	0.09
		0.15	0.54	0.14	0.55	0.08
		0.30	0.60	-0.01	0.59	-0.08
		0.45	0.63	-0.15	0.60	-0.22
		0.75	0.65	-0.38	0.60	-0.46
		0.93	0.63	-0.42	0.57	-0.50
	Depth Averaged Values:		0.60	-0.15	0.58	-0.22
7.8	1.14	0.09	0.54	0.24	0.56	0.18
		0.15	0.60	0.17	0.61	0.10
		0.45	0.61	-0.12	0.59	-0.19
		0.75	0.63	-0.28	0.59	-0.35
		1.11	0.64	-0.40	0.58	-0.48
	Depth Averaged Values:		0.61	-0.13	0.59	-0.21
8.4	1.44	0.09	0.54	0.15	0.55	0.09
		0.15	0.55	0.16	0.56	0.10
		0.45	0.61	-0.02	0.60	-0.09
		0.75	0.63	-0.13	0.61	-0.20
		1.05	0.59	-0.19	0.56	-0.26
		1.41	0.57	-0.19	0.54	-0.26
	Depth Averaged Values:		0.59	-0.07	0.58	-0.14
9	1.56	0.09	0.35	0.23	0.38	0.19
		0.15	0.51	0.08	0.51	0.02
		0.45	0.52	-0.06	0.50	-0.12
		0.75	0.59	-0.10	0.57	-0.17
		1.05	0.52	-0.10	0.50	-0.16
		1.35	0.59	-0.16	0.56	-0.23
		1.53	0.53	-0.07	0.51	-0.13
	Depth Averaged Values:		0.53	-0.05	0.52	-0.11
9.6	1.68	0.09	0.28	0.08	0.29	0.05
		0.15	0.30	0.05	0.31	0.01
		0.45	0.43	-0.04	0.43	-0.09
		0.75	0.49	-0.05	0.49	-0.11
		1.05	0.44	-0.01	0.44	-0.06
		1.35	0.37	0.07	0.38	0.03
		1.65	0.41	0.04	0.42	-0.01
	Depth Averaged Values:		0.41	-0.01	0.41	-0.04
10.2	1.11	0.09	0.31	-0.11	0.30	-0.15
		0.15	0.38	-0.12	0.37	-0.17
		0.45	0.38	-0.06	0.37	-0.11
		0.75	0.39	-0.01	0.39	-0.06
		1.08	0.27	0.10	0.28	0.07
	Depth Averaged Values:		0.36	-0.03	0.35	-0.08
10.8	1.08					
11.4	1.08					

Table 4. (continued)

SECTION 6

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.9	0.09					
1.8	0.12					
3	0.18					
3.6	0.18	0.09	0.53	-0.29	0.58	-0.16
	Depth Averaged Values:		0.53	-0.29	0.58	-0.16
4.2	0.21	0.09	0.55	-0.31	0.61	-0.18
		0.18	0.55	-0.39	0.62	-0.25
	Depth Averaged Values:		0.55	-0.34	0.61	-0.20
4.8	0.33	0.09	0.55	-0.06	0.55	-0.07
		0.15	0.63	-0.20	0.66	-0.04
		0.30	0.62	-0.35	0.68	-0.19
	Depth Averaged Values:		0.60	-0.20	0.63	-0.05
5.4	0.45	0.09	0.56	0.01	0.54	0.14
		0.15	0.59	-0.12	0.60	0.03
		0.33	0.62	-0.24	0.66	-0.09
		0.42	0.62	-0.38	0.69	-0.22
	Depth Averaged Values:		0.60	-0.16	0.62	-0.02
6	0.72	0.09	0.49	0.11	0.45	0.22
		0.15	0.55	0.08	0.51	0.21
		0.39	0.59	-0.09	0.59	0.05
		0.69	0.50	-0.27	0.55	-0.15
	Depth Averaged Values:		0.54	-0.07	0.54	0.06
6.6	0.90	0.09	0.27	0.02	0.26	0.09
		0.15	0.69	0.13	0.64	0.29
		0.45	0.70	-0.03	0.69	0.14
		0.69	0.70	-0.17	0.72	0
		0.87	0.66	-0.25	0.70	-0.09
	Depth Averaged Values:		0.64	-0.05	0.63	-0.10
7.2	0.90	0.09	0.66	0.16	0.61	0.31
		0.15	0.74	0.16	0.68	0.33
		0.30	0.71	0.01	0.69	0.18
		0.45	0.70	-0.12	0.71	0.05
		0.87	0.61	-0.24	0.65	-0.09
	Depth Averaged Values:		0.68	-0.06	0.67	0.10

Table 4. (continued)

SECTION 6

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
7.8	1.05	0.09	0.63	0.20	0.56	0.34
		0.15	0.69	0.14	0.64	0.30
		0.30	0.72	-0.12	0.73	0.06
		0.75	0.70	-0.19	0.73	-0.02
		1.02	0.62	-0.38	0.69	-0.22
	Depth Averaged Values:		0.68	-0.12	0.70	0.04
8.4	1.35	0.09	0.42	0.11	0.38	0.20
		0.15	0.43	0.06	0.40	0.16
		0.30	0.78	0.06	0.74	0.25
		0.45	0.78	-0.04	0.76	0.14
		0.90	0.74	-0.16	0.75	0.02
		1.32	0.64	-0.33	0.70	-0.16
	Depth Averaged Values:		0.68	-0.10	0.68	-0.07
9	1.5	0.09	0.51	0.44	0.40	0.55
		0.15	0.56	0.18	0.50	0.31
		0.30	0.53	-0.05	0.52	0.07
		0.90	0.68	-0.34	0.74	-0.16
		1.47	0.69	-0.07	0.69	-0.09
	Depth Averaged Values:		0.62	-0.11	0.63	0.04
9.6	1.5	0.09	0	0	0	0
		0.15	0.36	0.07	0.33	0.16
		0.45	0.68	0.15	0.63	0.30
		0.75	0.71	-0.01	0.70	0.16
		1.05	0.66	-0.12	0.67	0.04
		1.47	0.63	-0.10	0.64	0.05
	Depth Averaged Values:		0.58	-0.01	0.57	0.13
10.2	0.84	0.09	0.49	0.16	0.44	0.27
		0.15	0.59	0.04	0.56	0.18
		0.30	0.56	-0.04	0.55	0.09
		0.45	0.65	-0.04	0.64	0.11
		0.66	0.65	-0.03	0.64	0.12
		0.81	0.61	0	0.59	0.14
	Depth Averaged Values:		0.60	0.01	0.58	0.14
10.8	0.99					

Table 4. (continued)

SECTION 6A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Primary (m/s)	Secondary (m/s)
1.2	0.06					
1.8	0.09					
2.4	0.15	0.09	0.49	-0.25	0.48	-0.25
	Depth Averaged Values:		0.49	-0.25	0.48	-0.25
3	0.30	0.09	0.60	0.06	0.61	0.06
		0.15	0.58	0.02	0.58	0.02
		0.27	0.57	-0.16	0.57	-0.17
	Depth Averaged Values:		0.58	-0.02	0.59	-0.02
3.6	0.45	0.09	0.35	0.01	0.35	0.01
		0.15	0.59	0.02	0.59	0.02
		0.30	0.64	-0.05	0.64	-0.06
		0.42	0.66	-0.16	0.66	-0.17
	Depth Averaged Values:		0.56	-0.04	0.56	-0.04
4.2	0.51	0.09	0.60	-0.06	0.60	-0.07
		0.15	0.65	0.02	0.65	0.02
		0.30	0.73	-0.08	0.73	-0.08
		0.48	0.68	-0.12	0.68	-0.12
	Depth Averaged Values:		0.67	-0.06	0.67	-0.07
4.8	0.63	0.09	0.70	0.16	0.70	0.16
		0.15	0.67	0.10	0.67	0.09
		0.30	0.73	-0.09	0.73	-0.09
		0.60	0.72	-0.16	0.72	-0.17
	Depth Averaged Values:		0.71	-0.03	0.71	-0.04
5.4	0.84	0.09	0.66	0.09	0.66	0.08
		0.15	0.69	0.14	0.69	0.13
		0.30	0.77	0.09	0.77	0.08
		0.45	0.76	0.02	0.76	0.02
		0.60	0.76	-0.06	0.76	-0.07
		0.81	0.72	-0.08	0.72	-0.08
	Depth Averaged Values:		0.73	0.02	0.73	0.02
6	0.99	0.09	0.45	-0.02	0.45	-0.03
		0.15	0.55	0.14	0.55	0.14
		0.30	0.71	0.21	0.71	0.20
		0.45	0.71	0.18	0.71	0.18
		0.75	0.80	-0.03	0.80	-0.04
		0.96	0.73	-0.04	0.73	-0.05
	Depth Averaged Values:		0.69	0.07	0.69	0.07

Table 4. (continued)

SECTION 6A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
6.6	1.08	0.09	0.46	0.39	0.47	0.38
		0.15	0.56	0.39	0.56	0.38
		0.45	0.71	0.17	0.71	0.17
		0.75	0.76	-0.06	0.76	-0.07
		1.05	0.70	-0.16	0.70	-0.17
	Depth Averaged Values:		0.67	0.11	0.67	0.11
7.2	1.38	0.09	0.39	0.37	0.39	0.36
		0.15	0.56	0.28	0.56	0.28
		0.60	0.75	0.13	0.75	0.12
		0.90	0.69	0.05	0.69	0.05
		1.20	0.75	-0.13	0.74	-0.14
		1.35	0.69	-0.10	0.69	-0.10
	Depth Averaged Values:		0.67	0.10	0.66	0.10
7.8	1.68	0.09	0.24	0.28	0.24	0.28
		0.15	0.23	0.33	0.23	0.33
		0.45	0.59	0.23	0.60	0.22
		0.75	0.69	-0.05	0.69	-0.06
		1.05	0.66	-0.06	0.66	-0.07
		1.35	0.69	-0.14	0.69	-0.15
		1.65	0.64	-0.11	0.64	-0.11
	Depth Averaged Values:		0.58	0.04	0.58	0.03
8.4	1.74	0.09	0.03	0.26	0.03	0.26
		0.15	0.06	0.37	0.07	0.37
		0.30	0.24	0.08	0.24	0.07
		0.60	0.40	0.06	0.40	0.06
		0.90	0.62	-0.06	0.62	-0.07
		1.35	0.63	-0.05	0.63	-0.06
		1.56	0.58	-0.15	0.58	-0.16
		1.71	0.55	-0.13	0.55	-0.13
	Depth Averaged Values:		0.45	0.02	0.45	0.01
9	1.74	0.15	-0.06	0.17	0.06	-0.17
		0.30	0.10	0.13	0.10	0.13
		0.45	0.15	0.01	0.15	0.01
		0.60	0.31	0.03	0.31	0.03
		0.90	0.44	-0.05	0.44	-0.06
		1.35	0.56	-0.11	0.56	-0.11
		1.71	0.56	-0.08	0.56	-0.08
	Depth Averaged Values:		0.53	-0.05	0.52	-0.11

Table 4. (continued)

SECTION 6A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
9.6	1.38	0.09	-0.17	0.14	0.17	-0.14
		0.15	0.05	-0.04	0.05	-0.04
		0.45	0.11	-0.06	0.11	-0.07
		0.90	0.18	-0.03	0.18	-0.03
		1.20	0.08	-0.01	0.08	-0.01
		1.35	0.08	0.02	0.08	0.02
	Depth Averaged Values:		0.09	-0.02	0.12	-0.04
10.2	0.90					

Table 4. (continued)

SECTION 7

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.3	0.03					
0.6	0.18	0.09	0.05	-0.02	0.05	-0.03
Depth Averaged Values:			0.05	-0.02	0.05	-0.03
1.2	0.30	0.09	0.54	0.09	0.54	0
		0.15	0.52	0.02	0.52	-0.07
		0.27	0.32	0.01	0.32	-0.04
Depth Averaged Values:			0.47	0.05	0.47	-0.03
2.1	0.57	0.09	0.61	0.10	0.62	-0.01
		0.15	0.66	0.14	0.68	0.03
		0.30	0.65	-0.01	0.64	-0.12
		0.54	0.59	-0.13	0.56	-0.22
Depth Averaged Values:			0.63	0.01	0.62	-0.10
3	0.81	0.09	0.72	0.24	0.75	0.11
		0.15	0.78	0.04	0.78	-0.09
		0.30	0.74	0.02	0.73	-0.01
		0.60	0.74	-0.07	0.72	-0.20
		0.78	0.71	-0.10	0.68	-0.21
Depth Averaged Values:			0.74	0.01	0.73	-0.11
3.9	0.99	0.09	0.71	0.11	0.71	-0.01
		0.15	0.64	0.11	0.65	0
		0.45	0.73	0.11	0.74	-0.02
		0.60	0.80	-0.03	0.79	-0.17
		0.93	0.77	-0.04	0.75	-0.17
Depth Averaged Values:			0.74	0.04	0.73	-0.09
4.8	1.23	0.09	0.64	0.36	0.69	0.25
		0.15	0.76	0.32	0.80	0.19
		0.30	0.91	0.43	0.97	0.27
		0.60	0.80	-0.01	0.79	-0.14
		0.90	0.81	-0.09	0.79	-0.22
		1.20	0.80	-0.24	0.75	-0.37
Depth Averaged Values:			0.80	0.08	0.81	-0.05
5.7	1.47	0.09	0.57	0.26	0.60	0.16
		0.15	0.68	0.22	0.71	0.11
		0.45	0.76	0.03	0.75	-0.10
		0.75	0.82	0.06	0.82	-0.07
		0.90	0.77	-0.01	0.76	-0.14
		1.20	0.76	-0.02	0.75	-0.15
		1.44	0.74	-0.02	0.75	-0.15
Depth Averaged Values:			0.74	0.06	0.74	-0.07

Table 4. (continued)

SECTION 7

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
6.3	1.26	0.09	0.54	0.04	0.53	-0.05
		0.15	0.59	-0.11	0.56	-0.20
		0.45	0.70	-0.13	0.66	-0.24
		0.75	0.77	-0.11	0.74	-0.23
		0.99	0.73	0.04	0.72	-0.08
		1.23	0.64	0.13	0.65	0.02
	Depth Averaged Values:		0.68	-0.04	0.66	-0.15
7.2	0.51					

Table 4. (continued)

SECTION 7A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
0.9	0.06					
1.8	0.09					
2.4	0.18					
3	0.21					
3.6	0.45					
4.2	0.63	0.15	0.27	0.14	0.26	0.16
		0.45	0.20	0.14	0.19	0.16
		0.60	0.19	0.16	0.18	0.17
	Depth Averaged Values:		0.23	0.14	0.22	0.16
5.1	0.75	0.15	0.53	0.21	0.51	0.26
		0.45	0.52	0.17	0.50	0.22
		0.72	0.36	0.09	0.35	0.12
	Depth Averaged Values:		0.49	0.17	0.47	0.21
6	0.96	0.15	0.68	0.19	0.66	0.26
		0.45	0.64	0.17	0.62	0.24
		0.75	0.54	0.06	0.53	0.11
		0.93	0.56	0.09	0.55	0.14
	Depth Averaged Values:		0.62	0.14	0.60	0.20
6.9	0.96	0.15	0.63	0.19	0.61	0.25
		0.45	0.66	0.08	0.65	0.14
		0.60	0.68	0	0.68	0.07
		0.93	0.65	-0.12	0.66	-0.05
	Depth Averaged Values:		0.65	0.05	0.65	0.12
7.5	1.14	0.15	0.75	0.19	0.72	0.27
		0.30	0.78	0.10	0.76	0.17
		0.60	0.75	-0.02	0.75	0.05
		0.75	0.78	-0.10	0.78	-0.02
		0.90	0.78	-0.13	0.78	-0.05
		1.11	0.73	-0.19	0.74	-0.12
	Depth Averaged Values:		0.76	0	0.75	0.07

Table 4. (continued)

SECTION 7A

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)	Modified Velocities Primary (m/s)	Secondary (m/s)
8.1	1.38	0.15	0.75	0.10	0.73	0.17
		0.45	0.80	0.05	0.79	0.13
		0.75	0.81	-0.04	0.81	0.04
		1.05	0.78	-0.07	0.78	0.01
		1.35	0.73	-0.07	0.73	0
	Depth Averaged Values:		0.78	0	0.77	0.08
8.7	1.44	0.15	0.63	-0.17	0.64	-0.11
		0.45	0.87	-0.09	0.88	0
		0.75	0.82	-0.07	0.83	0.01
		1.05	0.82	0.02	0.82	0.10
		1.41	0.78	0.13	0.76	0.20
	Depth Averaged Values:		0.79	-0.05	0.79	0.03
9.3	1.38	0.15	0.29	-0.19	0.31	-0.16
		0.45	0.78	0.05	0.77	0.12
		0.75	0.53	0.10	0.52	0.15
		1.05	0.46	0.03	0.45	0.07
		1.05	0.46	0.03	0.45	0.07
		1.35	0.68	-0.10	0.69	-0.03
	Depth Averaged Values:		0.54	-0.02	0.54	0.04
9.9	1.05					

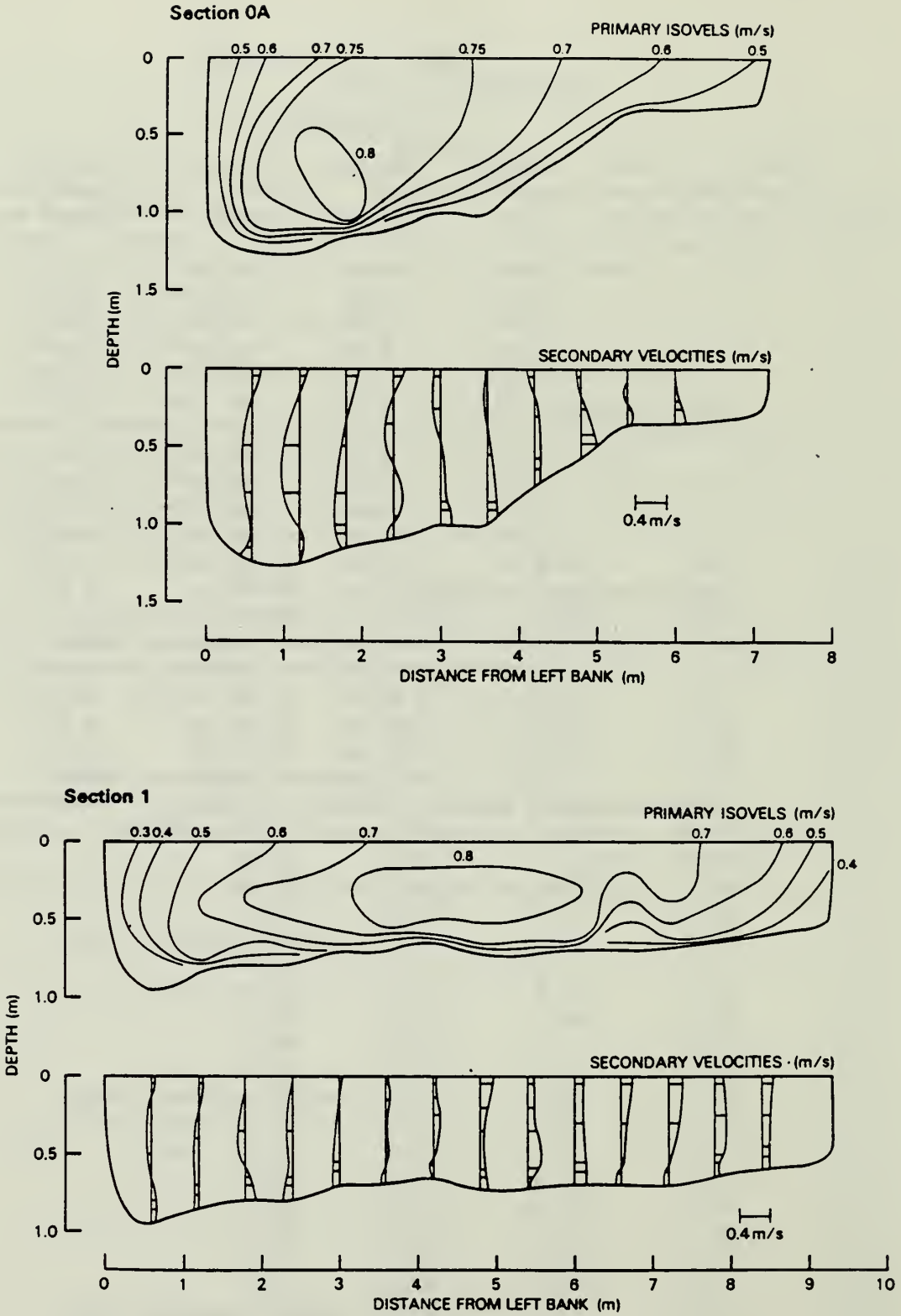


Figure 7. Primary Isovels and Secondary Velocities for Sections 0A to 7A, July 3-6, 1984

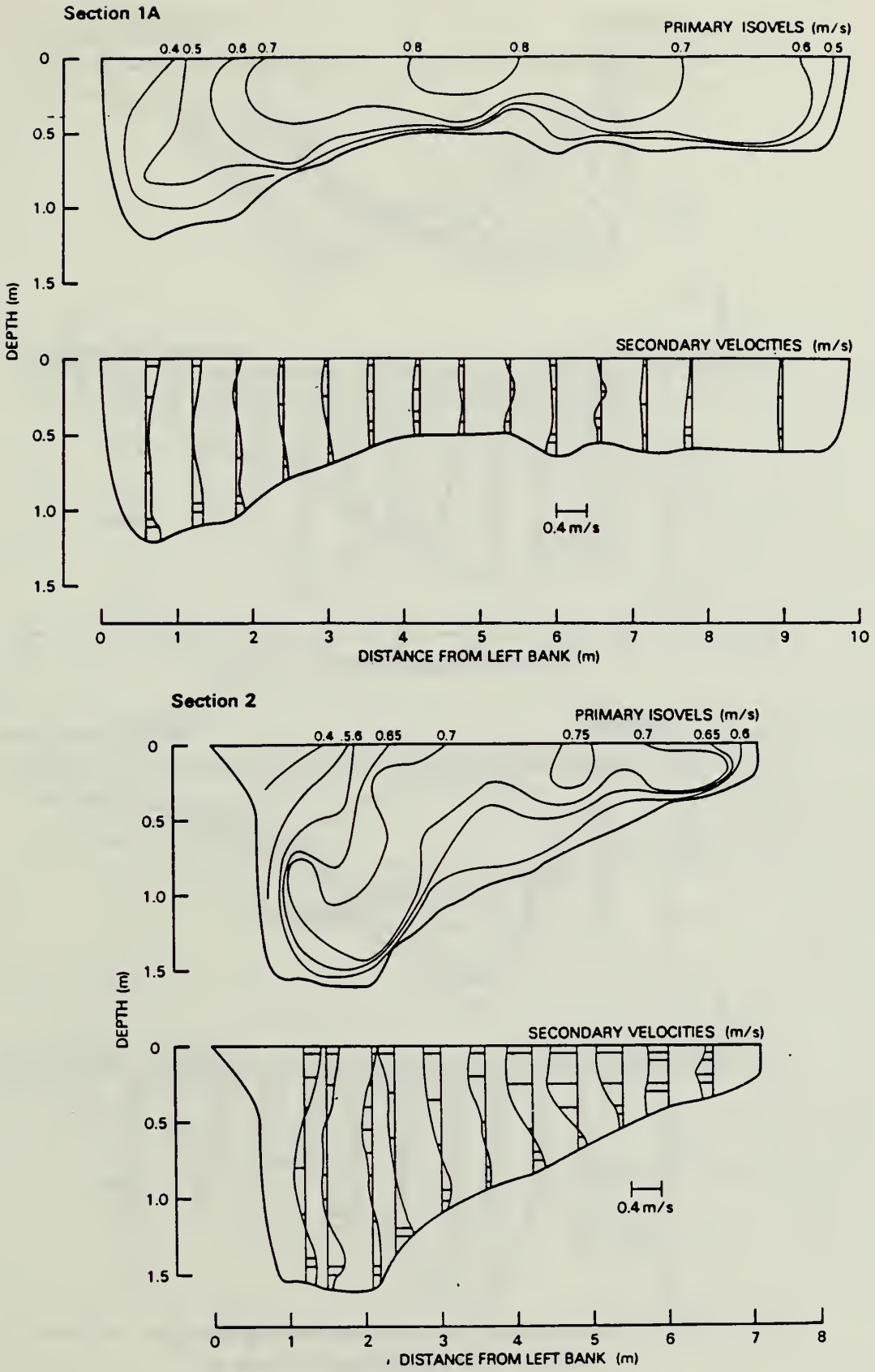

Section 1A
PRIMARY ISOVELS (m/s)
0.4 0.5 0.6 0.7 0.8 0.8 0.7 0.6 0.5
SECONDARY VELOCITIES (m/s)
0.4 m/s
DEPTH (m)
0 0.5 1.0 1.5
0 1 2 3 4 5 6 7 8 9 10
DISTANCE FROM LEFT BANK (m)
Section 2
PRIMARY ISOVELS (m/s)
0.4 .5.6 0.65 0.7 0.75 0.7 0.65 0.6
SECONDARY VELOCITIES (m/s)
0.4 m/s
DEPTH (m)
0 0.5 1.0 1.5
0 1 2 3 4 5 6 7 8
DISTANCE FROM LEFT BANK (m)

Figure 7. (continued)

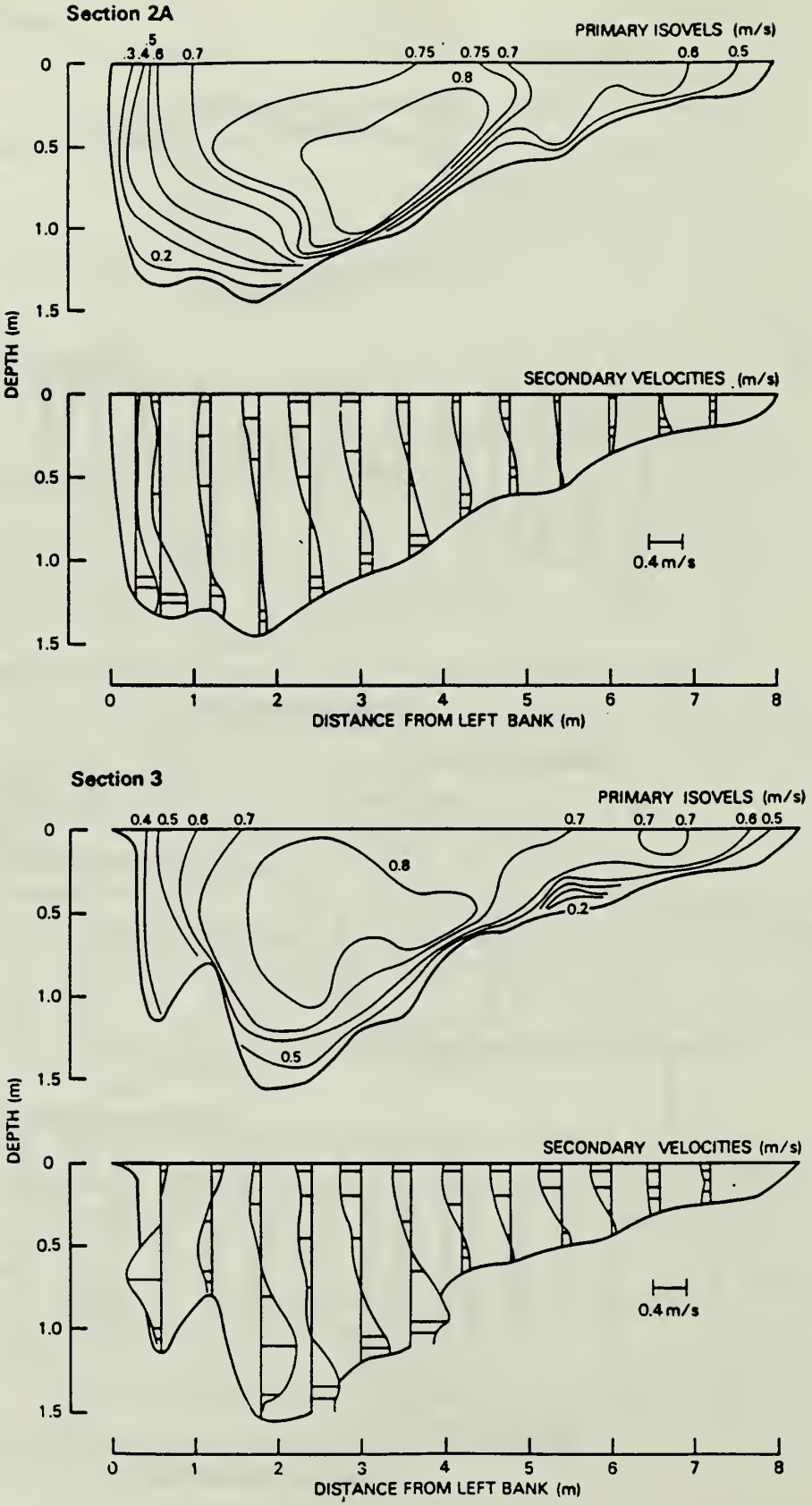


Figure 7. (continued)

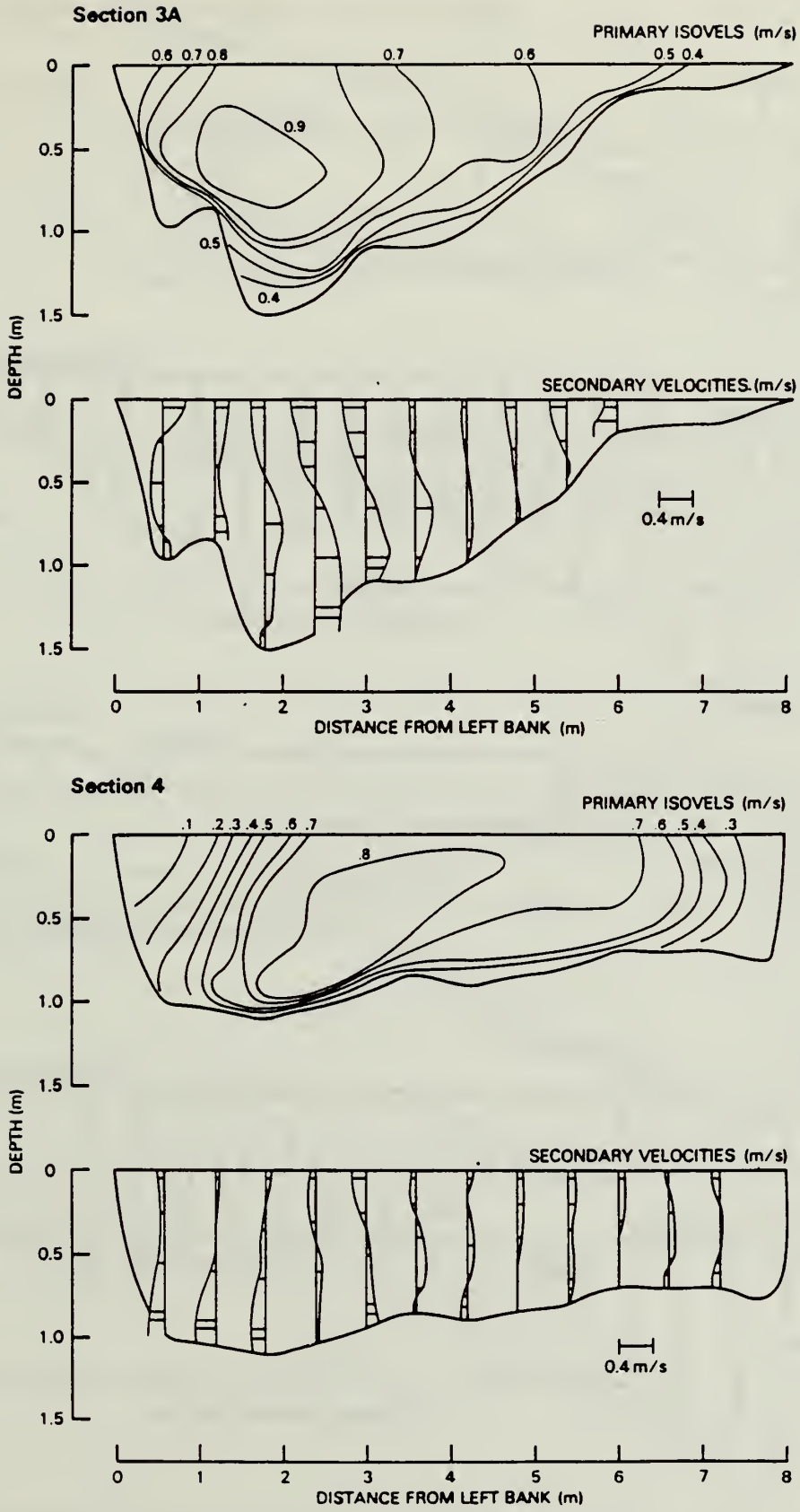


Figure 7. (continued)

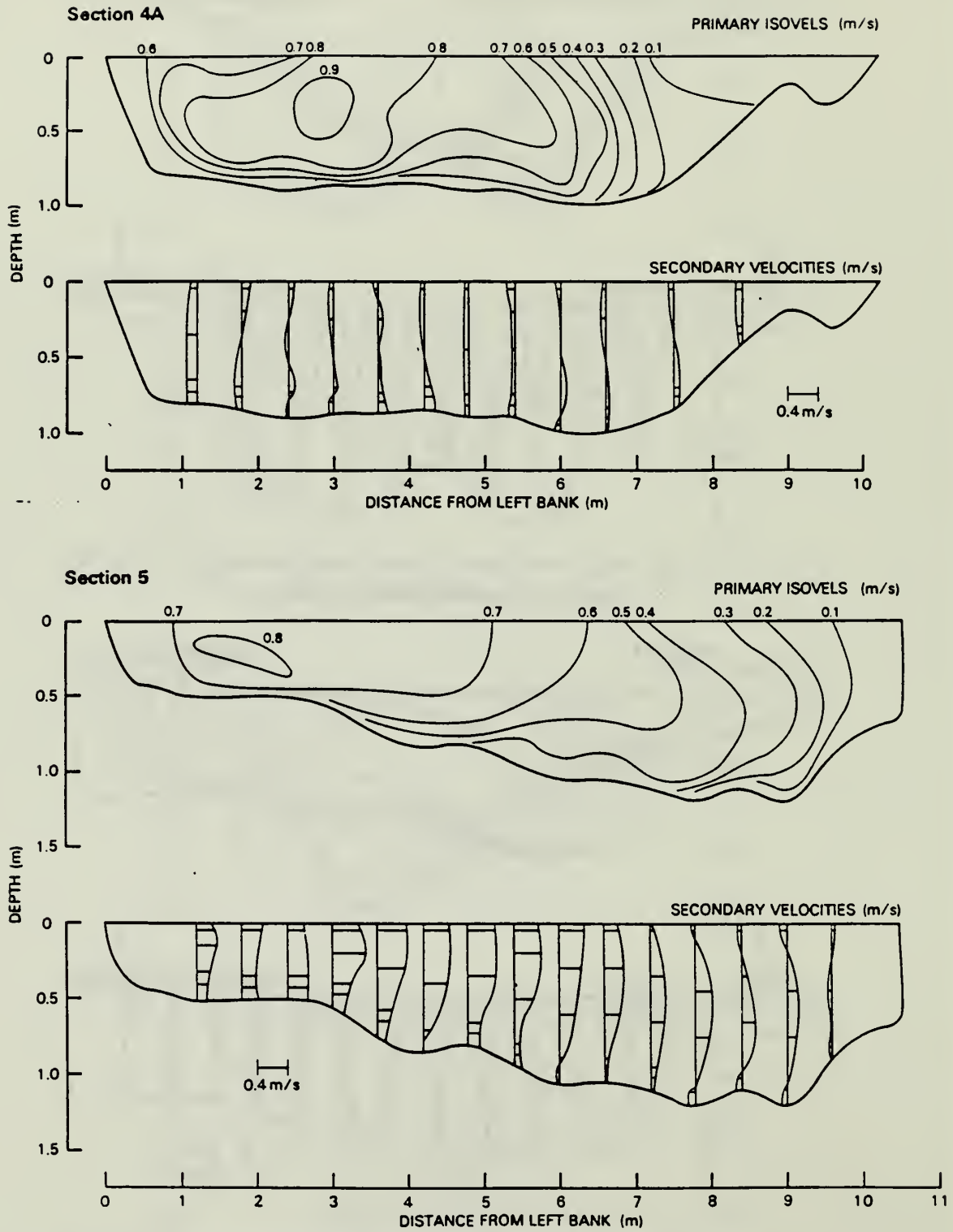
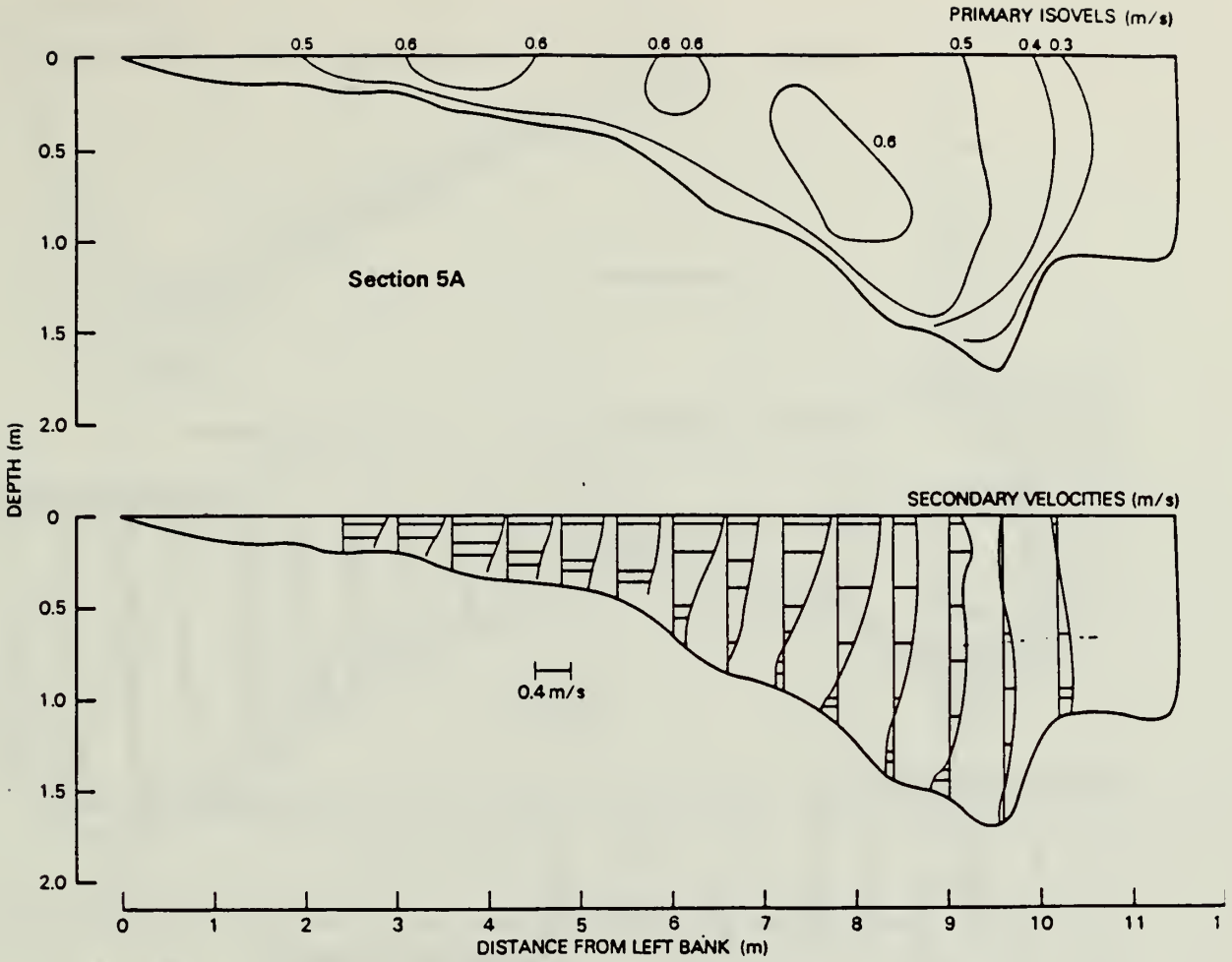


Figure 7. (continued)


PRIMARY ISOVELS (m/s)
0.5 0.6 0.6 0.6 0.6 0.5 0.4 0.3
0.6
Section 5A
DEPTH (m)
0 0.5 1.0 1.5 2.0
SECONDARY VELOCITIES (m/s)
0.4 m/s
0 1 2 3 4 5 6 7 8 9 10 11
DISTANCE FROM LEFT BANK (m)

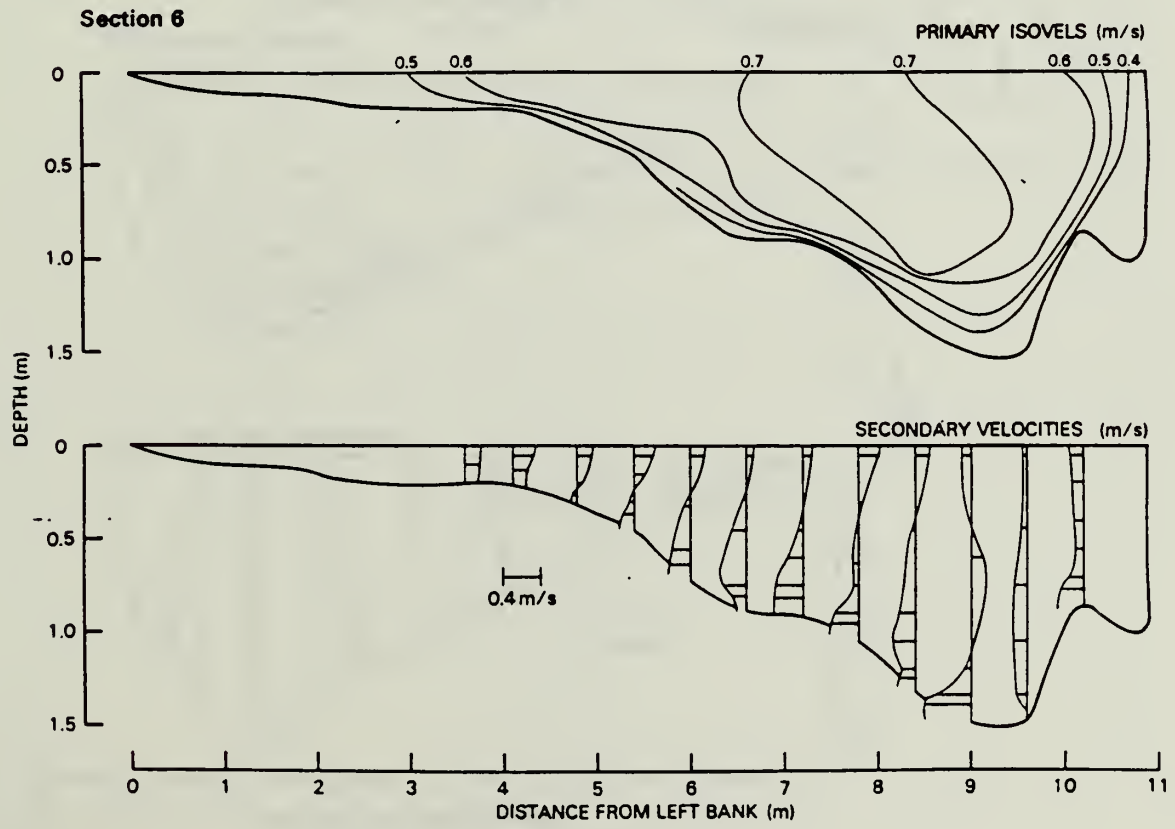
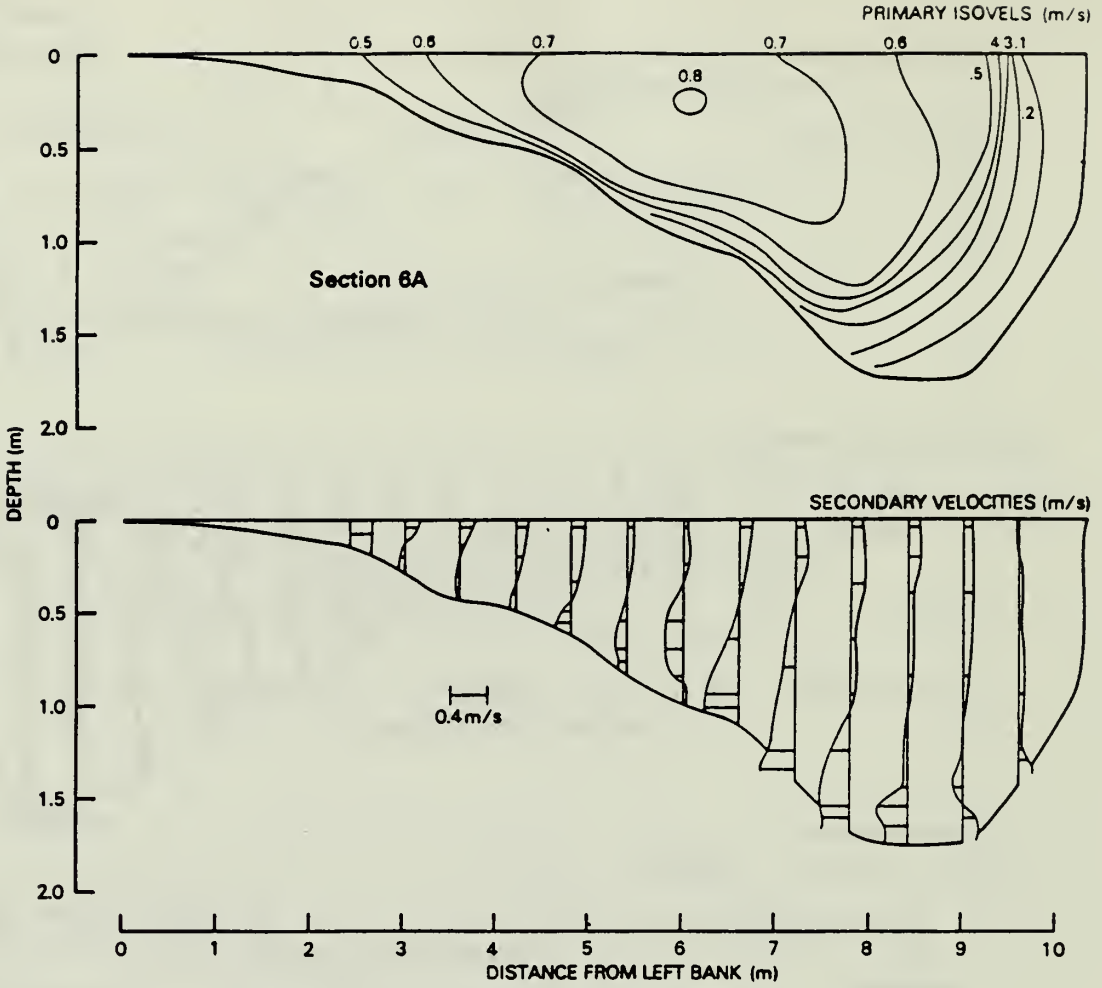

Section 6
PRIMARY ISOVELS (m/s)
0.5 0.6 0.7 0.7 0.6 0.5 0.4
DEPTH (m)
0 0.5 1.0 1.5
SECONDARY VELOCITIES (m/s)
0.4 m/s
0 1 2 3 4 5 6 7 8 9 10 11
DISTANCE FROM LEFT BANK (m)

Figure 7. (continued)



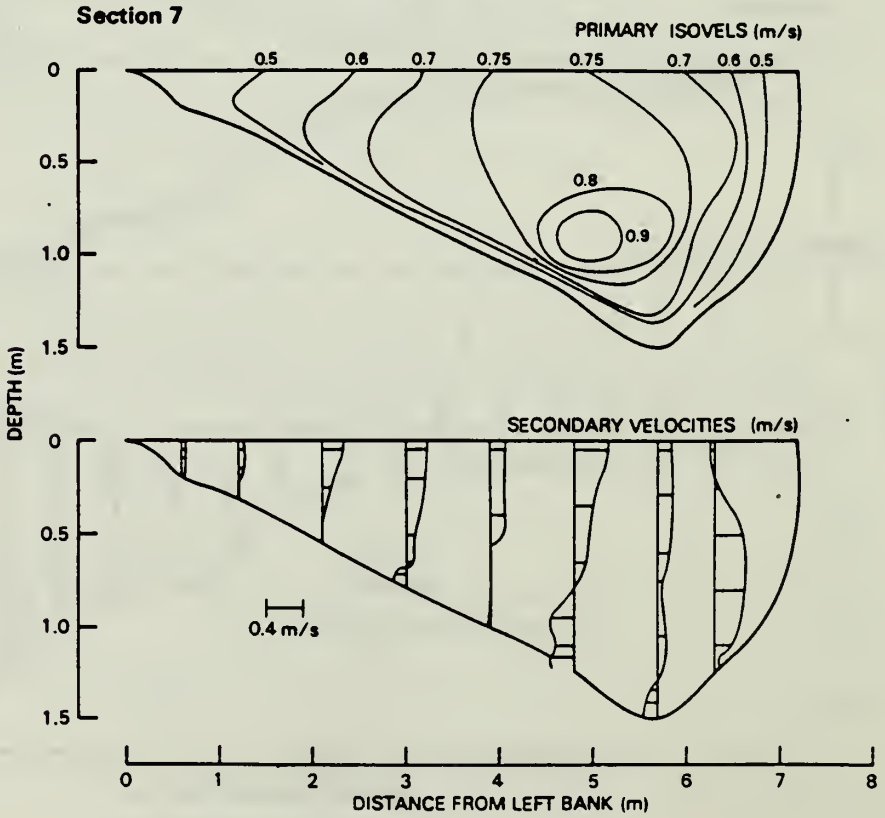


Figure 7. (continued)

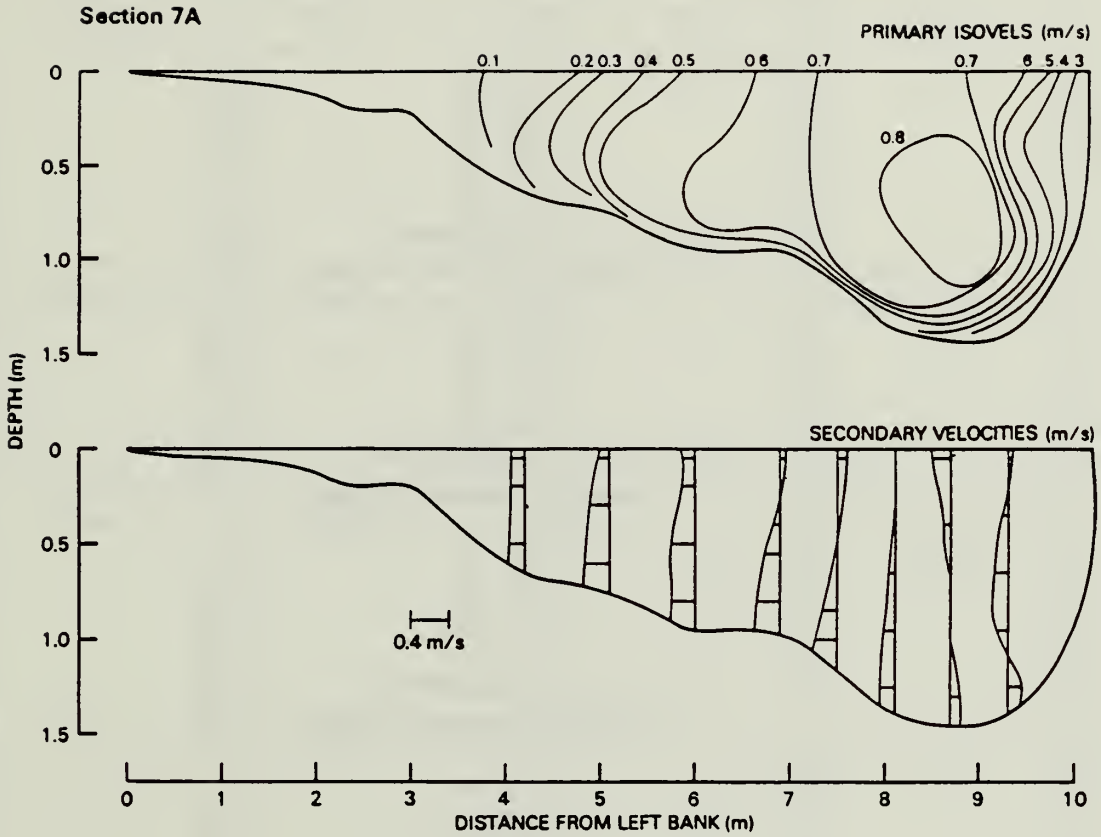


Figure 7. (continued)

Table 5. x-y Velocities for Sections 0 and 8

SECTION 0

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
0	1.20			
0.66	1.14	0.09	0.07	-0.06
		0.15	0.03	-0.02
		0.30	0.06	-0.04
		0.45	0.17	-0.01
		0.75	0.13	0.03
		1.11	0.05	-0.07
		Depth Averaged Values:	0.10	-0.02
1.2	1.11	0.09	0.04	-0.10
		0.15	0.07	0.03
		0.45	0.20	0.08
		0.75	0.17	0.05
		1.08	0.14	-0.14
		Depth Averaged Values:	0.14	0.01
1.8	1.14	0.09	0.23	-0.02
		0.15	0.32	0.13
		0.45	0.38	0.14
		0.75	0.32	-0.02
		1.11	0.09	-0.24
		Depth Averaged Values:	0.28	0.01
2.4	1.11	0.09	0.43	-0.05
		0.15	0.42	-0.07
		0.45	0.45	0.08
		0.75	0.31	-0.04
		1.08	0.09	-0.16
		Depth Averaged Values:	0.34	-0.03
3	1.32	0.09	0.28	-0.04
		0.15	0.34	-0.03
		0.45	0.48	0.05
		0.75	0.41	0.01
		1.05	0.31	-0.07
		1.29	0.23	-0.16
		Depth Averaged Values:	0.36	-0.03
3.6	1.26	0.09	0.34	-0.11
		0.15	0.41	-0.06
		0.45	0.53	0.03
		0.75	0.50	0.06
		1.05	0.42	-0.03
		1.23	0.45	-0.04
		Depth Averaged Values:	0.46	-0.01

Table 5. (continued)

SECTION 0

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
4.2	1.23	0.09	0.23	-0.14
		0.15	0.50	-0.14
		0.45	0.50	-0.05
		0.75	0.57	0.07
		0.99	0.54	0.04
		1.20	0.53	0
		Depth Averaged Values:	0.50	0
4.8	1.11	0.09	0.14	-0.12
		0.15	0.32	0
		0.45	0.67	0.13
		0.75	0.63	0.07
		1.08	0.62	0.06
		Depth Averaged Values:	0.54	0.05
5.4	1.05	0.09	0.53	-0.16
		0.15	0.55	-0.16
		0.45	0.67	-0.03
		0.75	0.72	0.07
		1.02	0.65	-0.04
		Depth Averaged Values:	0.64	-0.04
6	0.93	0.09	0.59	-0.06
		0.15	0.77	0.01
		0.45	0.75	0.11
		0.69	0.73	-0.03
		0.90	0.70	0.03
		Depth Averaged Values:	0.72	0.02
6.6	0.81	0.09	0.71	0.03
		0.15	0.81	0.04
		0.39	0.79	0.01
		0.54	0.76	0
		0.78	0.69	-0.02
		Depth Averaged Values:	0.76	0.01
7.2	0.69	0.09	0.78	-0.02
		0.15	0.74	-0.04
		0.36	0.74	-0.06
		0.48	0.70	-0.02
		0.66	0.64	-0.05
		Depth Averaged Values:	0.72	-0.04

Table 5. (continued)

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
		SECTION 0		
7.8	0.60	0.09	0.49	-0.04
		0.15	0.68	-0.07
		0.36	0.67	-0.08
		0.57	0.60	-0.02
		Depth Averaged Values:	0.62	-0.06
8.4	0.60	0.09	0.50	0
		0.15	0.54	0.03
		0.36	0.59	-0.04
		0.57	0.54	-0.01
		Depth Averaged Values:	0.55	-0.01
9.45	0.57			

Table 5. (continued)

SECTION 8

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
0.3	0.42	0.09	0.28	0
		Depth Averaged Values:	0.19	0
0.9	0.42	0.09	0.28	-0.01
		0.15	0.29	0.02
		0.39	0.31	0.07
		Depth Averaged Values:	0.29	0.03
1.8	0.69	0.09	0.42	0.01
		0.15	0.45	-0.01
		0.39	0.49	0.05
		0.66	0.44	-0.06
		Depth Averaged Values:	0.46	0
2.4	0.81	0.09	0.40	-0.14
		0.15	0.43	-0.09
		0.45	0.60	0.09
		0.78	0.63	0.10
		Depth Averaged Values:	0.54	0.02
3	0.72	0.09	0.63	0.12
		0.15	0.64	0.07
		0.45	0.71	0.10
		0.69	0.73	0.16
		Depth Averaged Values:	0.68	0.11
3.6	0.54	0.09	0.63	0.05
		0.15	0.63	0.06
		0.30	0.68	0.15
		0.51	0.77	0.23
		Depth Averaged Values:	0.68	0.13
4.2	0.63	0.09	0.62	0.01
		0.15	0.63	0.09
		0.36	0.75	0.14
		0.60	0.76	0.14
		Depth Averaged Values:	0.70	0.10
4.8	0.63	0.09	0.61	0.05
		0.15	0.60	0.06
		0.36	0.70	0.10
		0.60	0.76	0.10
		Depth Averaged Values:	0.68	0.08

Table 5. (continued)

SECTION 8

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
5.4	0.60	0.09	0.71	0.06
		0.15	0.73	0.11
		0.30	0.86	0.07
		0.57	0.79	0.08
		Depth Averaged Values:	0.79	0.08
6	0.66	0.09	0.61	-0.06
		0.15	0.63	0.03
		0.36	0.88	0.11
		0.63	0.80	0.03
		Depth Averaged Values:	0.76	0.04
6.6	0.57	0.09	0.82	-0.03
		0.15	0.88	0.02
		0.30	0.93	0.08
		0.54	0.84	0
		Depth Averaged Values:	0.87	0.02
7.2	0.57	0.09	0.61	-0.05
		0.15	0.86	-0.03
		0.36	0.94	0.05
		0.54	0.89	-0.05
		Depth Averaged Values:	0.84	-0.01
7.8	0.48	0.09	0.82	-0.15
		0.15	0.92	-0.17
		0.30	0.96	-0.09
		0.45	0.85	-0.06
		Depth Averaged Values:	0.89	-0.12
8.4	0.45	0.09	0.90	-0.23
		0.15	0.97	-0.26
		0.30	0.93	-0.12
		0.42	0.85	-0.15
		Depth Averaged Values:	0.92	-0.19
9	0.39	0.09	0.89	-0.33
		0.15	0.96	-0.27
		0.36	0.84	-0.24
		Depth Averaged Values:	0.90	-0.28
9.6	0.36	0.09	0.78	-0.31
		0.15	0.85	-0.35
		0.33	0.76	-0.28
		Depth Averaged Values:	0.80	-0.31

Table 5. (continued)

Distance from Bank (m)	Total Depth (m)	Height Above Bed (m)	Measured Velocities X (m/s)	Y (m/s)
		SECTION 8		
10.5	0.30	0.09	0.55	-0.41
		0.15	0.64	-0.38
		0.27	0.67	-0.38
		Depth Averaged Values:	0.61	-0.39
11.4	0.30	0.09	0.49	-0.26
		0.27	0.53	-0.32
		Depth Averaged Values:	0.51	-0.28
12	0.24	0.09	0.41	-0.18
		0.21	0.45	-0.19
		Depth Averaged Values:	0.42	-0.18
12.6	0.18	0.09	0.33	-0.16
		Depth Averaged Values:	0.33	-0.16

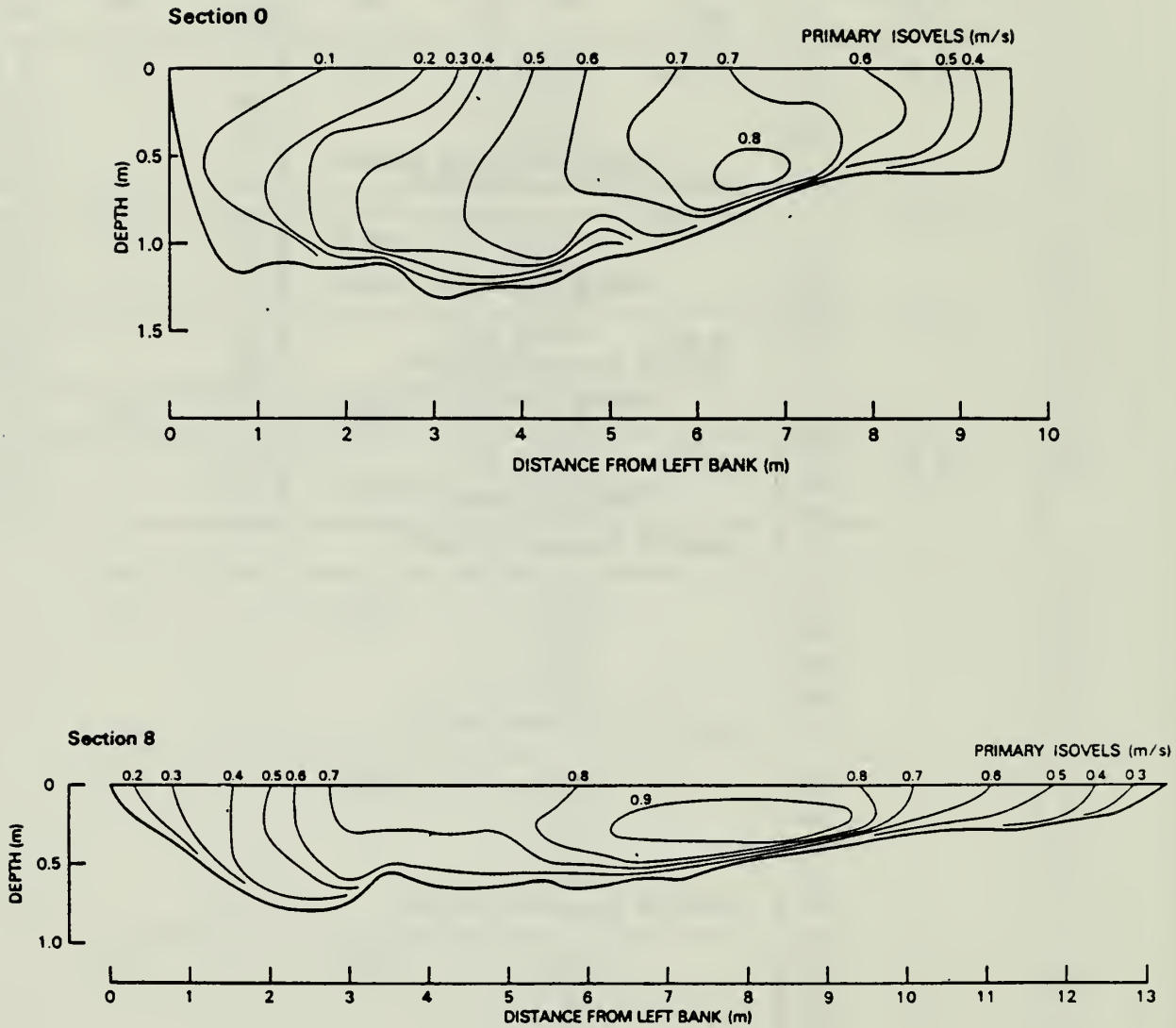


Figure 8. Longstream Isovels at Sections 0 and 8, July 3-6, 1984

CONCLUSIONS

The purpose of this study (continuing in 1985) is to build up as complete a data set as possible for a pair of consecutive bends in a sand-bed river with a mobile bed. In 1983 low- and medium-flow measurements were made and in 1984 these data were supplimented by measurements at bankfull stage. We are confident that the data collected are representative of flow patterns in the Fall River and that they are free from serious errors of measurement. It is our intention to analyze the data in the light of current theory on bend flow (see Appendix A) and to use the results, in the context of sediment movement and storage in Horseshoe Park, to help explain sediment dynamics in a meandering river (see Pitlick and Thorne, 1985, ref. on p. 2).

The 1983 data have also been used to test a new theoretical explanation of flow patterns close to the outer bank in meander bends. This work formed the basis for the graduate student work of Dr. Samira Rais.*

ACKNOWLEDGEMENTS

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*Rais, S., 1985, "Analysis of the Flow Close to the Outer Bank of a Meander Bend." Thesis submitted in partial fulfillment of the requirements for the degree Ph.D., Colorado State University, Fort Collins.

APPENDIX A

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Direct measurements of secondary currents in a meandering sand-bed river

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Natural channels often adopt a meandering course. Water flow in meander bends is three-dimensional, consisting of primary velocities which are tangential to the bend, and secondary velocities, which are in the radial plane. The pattern of secondary flow strongly affects the distribution of primary velocities. This in turn affects the distribution of erosion and deposition in the bend and the way in which the channel shifts and changes shape. Measurements of primary and secondary flows in a meandering gravel-bed river[1,2] show that, in addition to the widely recognized main secondary circulation driving surface water outwards and bed water inwards, there can be a small cell of reverse rotation at the outer bank. Further data have been collected in a sand-bedded river at low, intermediate and high discharges. The results confirm the existence of the main and outer bank cells but also indicate that in some bends the main cell does not extend to the inner bank. In fact, secondary flow at the inner bank of wide, shallow bends is directed radially outwards over the whole flow depth at all in-channel flows. This indicates that some models of bend flow and channel development may be significantly in error.

Secondary currents are defined as currents that occur in a plane normal to the axis of primary flow[3]. In meander bends, they develop by skewing of cross-stream vorticity into a long-stream direction[3,4]. The resulting skew-induced secondary circulation carries fast surface water towards the outer bank and slower bed water towards the inner bank.

At the outer bank, the primary flow, secondary circulation, and bank interact to produce a small cell of reverse rotation to the skew-induced cell. This cell occupies the channel to a distance one or two times the bank height away from the bank. Although this is a small proportion of the cross-section in most rivers, the outer bank cell is still important because it strongly affects the distribution of boundary shear stress, thereby influencing bank erosion processes[5,6].

In the central part of the channel, helical skew-induced flow produces inward velocities near the bed, which sweep bedload towards the inner bank. Sediment accumulation as a point bar at the inner bank gives the channel an asymmetrical cross-section. The balance between the transverse, upslope component of fluid drag on a bedload particle, and the transverse, downslope component of particle weight has been used as the basis for models of bed topography in bends[7,8]. This view of secondary flow-point bar interaction has been challenged recently[9]. Dietrich and Smith suggest that secondary flow above the point bar is directed radially outwards over the whole flow depth and that the helical skew-induced cell is confined to the deepest, or thalweg, portion of the cross-section. Sediment accumulation is then concentrated on a steep transverse slope called the point bar face, between the upper point bar (point bar platform) and the thalweg, where near bed flow converges and there is strong upwelling. Bridge[10] suggests that this pattern of flow and point bar building is a characteristic of point bar emergence at flows below about two-thirds bankfull. He suggests that at such low stages the point bar topography causes flow convergence at the bend entrance, but that such patterns are replaced by helical flow at formative (that is, bankfull) discharge.

To help to resolve this discussion, data were collected in this study over a range of discharges in meander bends of the Fall River in Rocky Mountain National Park, Colorado. The reach studied has a bankfull capacity of about 4 $m^3 s^{-1}$ and well developed meanders with a sinuosity of 2.2. The annual hydrograph is dominated by snowmelt runoff, resulting in long periods of almost steady bankfull flow in May, June and July. The gradient is ~0.1%. The bed material is sand, $D_{50} = 1.0$ mm, moving in dunes, ripples and as suspended load. Sediment availability has been greatly increased by erosion associated with the failure of Lawn Lake Dam on the Roaring River (an upstream tributary) on 15 July 1982. As a result, the bed is mobile at all discharges and point bars in the bends respond quickly to changes in flow stage.

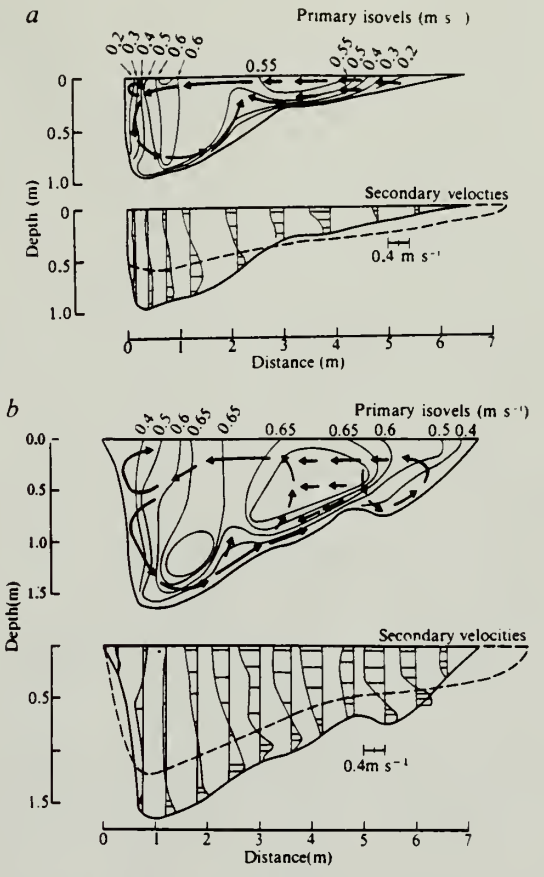

Fig. 1 Upstream bend apex, discharge: *a*, 1.7 $m^3 s^{-1}$; *b*, 4.0 $m^3 s^{-1}$. Dashed channel section represents that at the previous measurement section, ~6 m upstream.

Measurements were made at low, intermediate and bankfull stages, corresponding to discharges of 1.7, 2.8, and 4.0 $m^3 s^{-1}$. Long and cross-stream velocities were measured using an electromagnetic current meter capable of measuring two mutually perpendicular velocity components with an accuracy of ±3 mm s^{-1}. All measurements were made from temporary bridges aligned at right angles to the outer bank, and care was taken to work only over dune crests, avoiding separation zones on the lee side of dunes. Data were collected at 18 sections evenly spaced along the channel through two consecutive bends. The complete data set is available[11,12] but because of limitations of space, only data for the intermediate and high flow at the bend apices are reported here. However, these sections do typify the different patterns found in the two bends. The long and cross-stream velocities were resolved into primary and secondary components using the method based on three-dimensional continuity recommended by Dietrich and Smith[9]. The results are shown in Figs 1, 2.

At both sections and flows the salient feature of the secondary circulation is the helical, skew-induced cell. However, close to the outer bank, a small cell of reverse rotation is clearly present, especially at bankfull flow. These cells are associated with distortion of the primary isovels and depression of the maximum primary velocity below the free surface in the outer bank region.

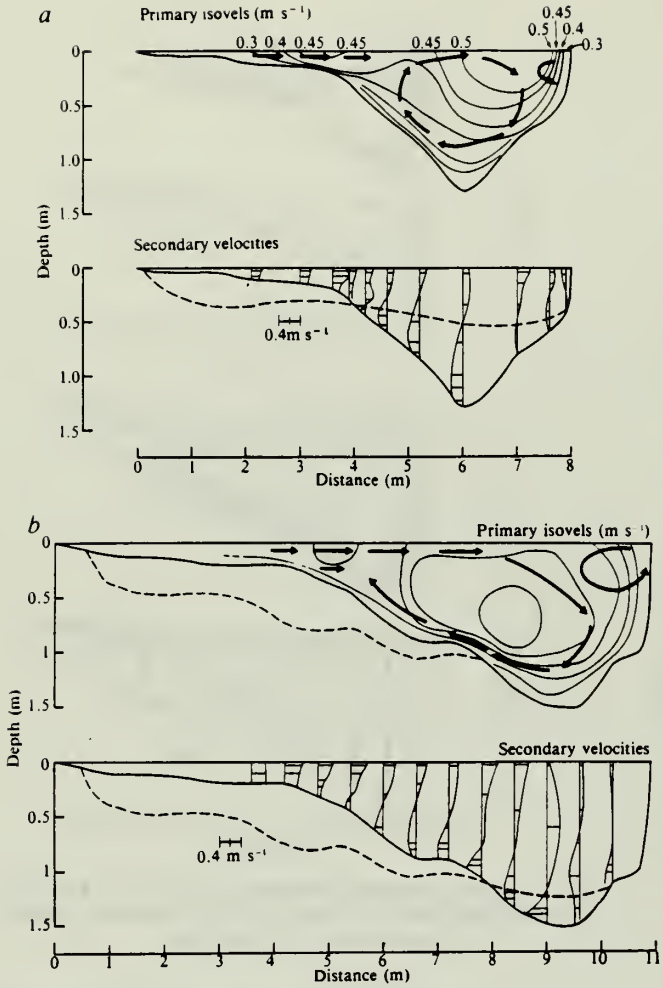

Fig. 2 Downstream bend apex, discharge: *a*, 1.7 $m^3 s^{-1}$; *b*, 4.0 $m^3 s^{-1}$. Dashed channel section represents that at the previous measurement section, ~4 m upstream.

The outer bank cell occupies the channel to a distance 1-2 times the bank height away from the outer bank, as observed elsewhere[5,9,10] and predicted theoretically[13].

The pattern of primary and secondary flows in the outer half of the channel changes little with stage at a bend, and is similar at both apices. This robustness is not present in the flow pattern in the inner half of the channel, where the two bends react differently to changing stage.

At intermediate flow, secondary flow over the point bar is directed radially outwards over the whole depth, as predicted and observed by Dietrich and Smith and by Bridge[9,10]. The reason for this is the dominance of the centrifugal force acting outwards over the hydrostatic pressure gradient, acting inwards. Also, the flow is shelving and narrowing in the longstream direction at the inner bank, as indicated in Figs 1*a* and 2*a* by the dashed lines showing the cross-section just upstream from the bend apex. Consequently, water is driven radially outwards to maintain continuity, leading to outward secondary flow. These arguments agree with the explanation put forward by the previous researchers[9,10].

At bankfull stage, the two bends show different flow patterns in the inner half of the channel. At the upstream bend, outward flow has been replaced by helical flow over most of the width, as predicted by Bridge[10]. The point bar has been scoured and reprofiled by the high flow and this, combined with the increased stage at almost constant width, has significantly increased the importance of the cross stream hydrostatic pressure gradient, which is now able to drive bed flow inwards. This is not the case at the downstream bend. Here, outward flow over the point bar persists up to bankfull discharge. The reason for this is that the width increases markedly with stage at the downstream bend, so that both the depth and the hydrostatic pressure gradient over the point bar remain small (Fig. 2*b*). Also, the point bar is more prominent in the downstream bend, so that shelving in the downstream direction is maintained at bankfull flow (Fig. 2*b*). This is not the case at the upstream bend, where high flow scouring produces deepening downstream at the inner bank (Fig. 1*b*).

We conclude that both patterns of flow in the inner half of the channel are possible and do occur in nature, depending on the morphology of the channel cross-section. Of particular importance is the stage-width relationship. Where there is marked widening with stage, outward flow persists to bankfull flow, but where width is almost constant with stage, helical flow expands almost to the inner bank. A quick survey of the Fall River bends revealed about equal numbers of bends falling into each category. As all the bends have the same bankfull discharge, sediment load, and bed and bank materials, there seems to be no obvious reason for the different morphologies, raising the possibility of there being two stable bend sections for a given set of independent controls. Clearly, point bar-flow interaction is a topic deserving further consideration and study.

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